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ABSTRACT

It has often been suggested by economists and other social scientists that the educational system may conveniently be viewed as a production process. The primary output of this process is an increase in the student's stock of knowledge and skill, and the inputs to the process including the student's time (the productivity of which depends upon a previously acquired stock of human capital), the time of instructors, and a variety of forms of capital equipment which augment the instructional process. In order to examine the usefulness of this view, this paper attempts to estimate the relationship between specific measures of the output of the educational process at the college level and proxies for each of the dimensions of input specified above. These estimates are derived by postulating rather simple functional relationships between these input and output measures--and using multiple regression analysis to estimate the parameters of these functions. In estimating these parameters, data is used describing the inputs and outputs of the college experience for a large sample of students entering college in 1960. A 26-item bibliography is included. (Author)

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GRADUATION, GRADUATE SCHOOL ATTENDANCE, AND INVESTMENTS IN COLLEGE TRAINING

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I. INTRODUCTION

It has often been suggested by economists and other social scientists that the educational system may conveniently be viewed as a production process.[1] The primary output of this process is an increase in the student's stock of knowledge and skill. This output acquires value by augmenting the individual's ability to produce other goods and services. The inputs to this process include the student's time (the productivity of which depends upon a previously acquired stock of human capital), the time of instructors, and a variety of forms of capital equipment which augment the instructional process. Where students acquire their education in groups, it may be well to recognize that the input to this process by one student may affect not only his own output but the output of other students as well.[2]

In order to examine the usefulness of this view, we have attempted in this study to estimate the relationship between specific measures of the output of the educational process at the college level and proxies for each of the dimensions of input specified above. These estimates are derived by postulating rather simple functional relationships between these input and output measures -- which we refer to as educational production functions -- and using multiple regression analysis to estimate the parameters of these

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[1]This view underlies the work in the area of Becker, Schulz, Thurow, Weisbrod and others. For the most explicit discussion, see Yoram Ben Porath, "The Production of Human Capital and the Life Cycle of Earnings," Journal of Political Economy, August 1967, pp. 352-365.

[2]This possibility has often been ignored by economists, but not by sociologists. See, for example, James S. Coleman, et. al., Equality of Educational Opportunity, Washington: U.S.G.P.O., 1966, and Alexander W. Astin, "Undergraduate Achievement and Institutional Excellence," Science, Vol. 161, No. 3842, August 16, 1968, pp. 611-617.

functions. In estimating these parameters, we use data describing the inputs and outputs of the college experience for a large sample of students entering college in 1960.

We have three primary objectives in mind in attempting to estimate the parameters of these production functions. As suggested above, this analysis provides a means for evaluating the viability of viewing the educational system as a production process. The failure to observe consistent relationships between the supposed inputs and outputs of this process would cast doubt on the usefulness of this view.

If this approach does produce consistent input-output relationships, the production function provides a useful device for evaluating the efficiency of alternative patterns of investment. In particular, this production function may provide a guide for students, educational administrators, and the public generally in attempting to improve the efficiency of educational investment.

Finally, since the output of the educational system, once produced, cannot be freely bought and sold, the process by which educational services are produced has important implications for the distribution of educational services. For a variety of reasons, students from high-income family backgrounds possess a larger stock of human capital upon entry to college than students from low-income family backgrounds. In addition, these students are capable of making larger financial investments in college than those from low-income backgrounds. The production function provides a mechanism for evaluating the importance of each of these advantages and enables us to assess the usefulness of alternative means for achieving a more egalitarian distribution of educational output.

The remainder of this study is divided into four parts. First, we examine the results of a number of other studies of the relationship between specific inputs and outputs of the college process. In Section III, the model and estimating procedure used in this study are discussed in some detail; and, in Section IV, the estimated parameters of that model are evaluated. Section V summarizes the primary policy implications of this study.

II. OTHER STUDIES

While a number of other studies have examined the relationship between educational inputs and outputs, it is difficult to generalize from the results of these studies. Thus, a study by Hunt [16] examines, for a sample of college graduates, the relationship between earnings in 1947, ability level, and expenditure per pupil at the college they attended. This study suggests that after controlling for the student's ability level, expenditure per pupil has little effect on earnings. In examining the relationship between earnings and school expenditures, Hunt controls for several factors which may themselves be responsive to college quality. These include the student's likelihood of graduation from college, the student's decision to attend graduate school, as well as certain aspects of the student's career choice. Moveover, expenditure per pupil at these colleges as of a point in time is used to measure college quality over the period of nearly half a century. Both of these factors may have reduced the magnitude and statistical significance of the relationship between college quality and earnings. On the other hand, another aspect of the model operates in the opposite direction. Hunt uses both the average ability of the student body and expenditure per pupil to measure college quality, but these measures are not examined simultaneously. Consequently, the estimated effect on earnings of increasing expenditure per pupil at a college may include the effect of increasing the quality of the student body at the college.

A study by Weisbrod and Karpoff [26] also examines the relationship between the earnings of college graduates, their ability, and the quality of the college they attended. In this study, both of these inputs appear related to earnings, but the authors do not test the statistical significance of this relationship. Moreover, since the measure of college quality is a subjective one, it would be difficult to use these results to evaluate the efficiency of alternative patterns of educational investments.

The most recent examination of this relationship is that of Daniere and Mechling [11]. This study constructs an earnings composite for each of a number of colleges. This composite, which is based on the graduation rate at each college and the career pattern of graduates observed five years after graduation, is then related to the average ability of the student body and the level of expenditure per pupil at these colleges. The results indicate positive returns on increased expenditure per student and a particularly high return in low-expenditure, high-ability institutions. Unfortunately, Daniere and Mechling also fail to test the statistical significance of these relationships. Moreover, the use of expenditures as the single measure of college quality may, as we suggested above, overestimate the returns to educational investment.

A number of studies examine the relationship between the quality of the inputs to a student's undergraduate experience and likelihood of attaining a Ph.D. degree. Knapp and Goodrich [19] suggest that there is a substantial difference between high and low quality colleges in this regard. However, as other authors point out, this study fails to control for differences in the student's input to this process. Holland [15], Thislethwaite [25], and Astin [1] all try to remedy this deficiency, and their studies suggest a more modest role for college quality. Astin's study does suggest that increasing the ratio of faculty to students increases the fraction of entrants who receive Ph.D. degrees.

One of the most complex models of the educational process is that examined by Astin in a recent article in Science [2]. In this study, the output measures are the student's scores on the Graduate Record Examination's achievement tests in the natural sciences, humanities, and the social sciences. The scores on these tests by each of 669 students in 38 colleges and universities are related to nearly 170 measures of educational input. These include over 100 measures of student input such as the student's scores on aptitude tests administered prior to college entry, measures of the student's socio-economic background, characteristics of the high school attended, and measures reflecting the student's career choice. In measuring the characteristics of the student's college, the study included the average ability level of students in that college, measures of expenditure per student in the college, enrollment level, academic competitiveness, the region and size of the community in which the college is located. In addition, a number of measures were included reflecting interaction among these variables.

On the basis of regressions relating these inputs to each of the three output measures, the study concludes that college characteristics have little effect on student achievement. This conclusion is based on the fact that after controlling for measures of student input, only two measures of college input -- library expenditures and a composite reflecting total affluence of the college -- have a significant effect on college output.

This conclusion may be misleading. Given the number of variables used in this analysis, it is not surprising that many of the school input measures have no significant effect on student performance. Due to the high degree of multicollinearity among these input measures, there is little independent variance in any of the school inputs. Therefore, the effects of these inputs can only be estimated with substantial error. Consequently, although Astin is not able to reject the hypothesis that the effect of these variables is zero, he would also be unable to reject the hypothesis that they have a substantial effect. This should not be taken as evidence that these variables have no effect, but as evidence that Astin's model is far too complex to be evaluated with the data available.[3]

In summary, the literature on relating college inputs and outputs is rather inconclusive with respect to the impact of increasing college quality. Those studies which have failed to show a significant relationship between the level of investment per student and measures of output all appear to have examined measures of input which may have been too highly disaggregated given the quality of the available data. On the other hand, studies which show a substantial return on these investments have generally failed to test for statistical significance or have used input measures which are so highly aggregative as to be of questionable usefulness.

[3]For a useful discussion of the difficulties inherent in the approach used by Astin to assess the importance of inputs to the educational process, see Samuel Bowles and Henry M. Levin, "The Determinants of Scholastic Achievement -- An Appraisal of Some Recent Evidence," in Journal of Human Resources, Vol. III, No. 1, Winter 1968, pp. 3-24; Glen C. Cain and Harold W. Watts, "Problems in Making Policy Inferences from the Coleman Report," in American Sociology Review, Vol. 35, No. 2, April 1970, pp. 228-241; Samuel Bowles and Henry M. Levin, "More on Multicollinearity and the Effectiveness of the Schools," in Journal of Human Resources, Vol. III, No. 3, Summer 1968, pp. 393-400.

III. THE MODEL

Data Sources

In analyzing the production of educational services, we have used data on students from the Project Talent data bank.[4] The students included in the sample are males who were high-school seniors in 1960, who responded to both follow-up questionnaires, and who had entered four-year colleges as full-time students in September of that year. Various forms of nonresponse and the requirement that each student in the final sample attend a college attended by at least ten other students from the sample reduced the final sample to about 3,000 students attending 200 different colleges. The data on these students from the Project Talent Survey is supplemented by data on the colleges they attended from the Higher Education General Information Survey.[5]

Measures of Output

In assessing the college output of these students, two dichotomous mea-

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[4]The Project Talent data bank is a cooperative effort of the U.S. Office of Education, the University of Pittsburgh, and the American Institutes for Research. This data bank is based on a survey of about 400,000 students who were enrolled in nearly 1,000 high schools in 1960. An extensive battery of aptitude and personality tests and a questionnaire assessing family background, plans, and interests were administered to these students in May of 1960. This data has been augmented by follow-up surveys administered to these students one and five years after their scheduled date of high school graduation. In acknowledging the contribution of Project Talent, we point out that the design and interpretation of the research reported herein are solely our own responsibility.

[5]The higher education General Information Survey is an on-going project of the National Center for Educational Statistics of the U.S. Office of Education. It is an annual survey of all institutions of higher education in the United States and contains data on the enrollment levels, the employees, the finances, degrees granted and the growth plans of these institutions. In this study, we used data on finances, enrollment, and employees from the 1966 H.E.G.I.S. Survey.

sures are used. The first of these is a variable which takes on the value one if the student graduates within five years and is zero otherwise. The second measure, which is assessed only for students who graduate within five years, takes on the value one if the student goes on to graduate school and is zero otherwise. The estimated relationship between these measures and various inputs reflects the effects on the probability of college graduation or graduate school attendance of varying each of these inputs while holding all other inputs constant.

There are two primary drawbacks to these variables as measures of college output. First, they clearly do not represent a complete specification of the output of the college process. There are many other dimensions of success in college which are not reflected either by graduation or graduate school attendance. This, of course, limits our ability to generalize from the results of this study. If we find no significant relationship between these measures and the inputs to the educational process, it may not follow that the production model is inappropriate to the educational process but only that these are inappropriate measures of output. On the other hand, if significant relationships are uncovered in this analysis, this should serve to encourage application of this model to other indices of output as well.

A second difficulty stems from the subjective nature of these output measures. The standards for graduation may vary from institution to institution and from student to student, and moreover, these standards may themselves be an increasing function of the inputs to the educational process. Similarly, while the model explored in this study suggests that a student's likelihood of attending graduate school depends upon the quality of his undergraduate experience, it is also likely to depend upon the student's assessment of the attractiveness of the other opportunities available to him at the time of graduate school attendance. The quality of these opportunities may also depend upon the quality of the student's undergraduate experience. Consequently, the estimated relationships between these output measures and the inputs to the educational process are likely to underestimate the effect of these inputs on the quality of the undergraduate experience.

Despite these limitations, there are good reasons for using these variables as measures of output. After adjustment for the costs of these investments, students with graduate training earn more than graduates who do not go into graduate school, and both of these groups earn more, on average, than college entrants who do not graduate. The relationship between these events and earnings suggests that college graduates have acquired more productive capacity from college than dropouts and that students attending graduate school have acquired more than those who terminate their formal education upon graduation. If, as has often been alleged, the objective of investment in education is to increase productive capacity, then it should be useful to explore the relationship between the level of this investment and the likelihood of these events. Moreover, given the relationship between these events and lifetime earnings, they should be of interest to students even if they are unrelated to productivity.

Even in the absence of a relation to earnings, these events represent viable measures of college output. In the current context, a student who fails to graduate is generally dissatisfied with the college he attends or has been found a less-than-satisfactory student by the faculty of that college. By the same token, graduate school attendance is a reflection of a high level of satisfaction with the educational process. The prospective graduate student is sufficiently satisfied with his undergraduate experience to extend this process further. The graduate or professional school he attends, in admitting this student, is expressing satisfaction with the calibre of his undergraduate program and his performance in that program. In both cases, it is useful to see whether increasing the level of input to the educational process can reduce the probability of unsatisfactory outcomes while increasing the likelihood of more satisfactory outcomes.

Functional Form and Estimation Procedure

The output measures used in this analysis are assumed to be linear, additive functions of the inputs to the educational process. That is:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_n X_{ni} + \varepsilon_i \qquad (1)$$

where:

Y_i = a dummy variable which takes on the value one if the ith entrant (graduate) graduates (attends graduate school) and is zero otherwise

X_{ji} = a measure of the jth input to the educational process for the ith student

β_j = the parameters of the model

ε_i = a stochastic term

We have used multiple regression analysis to estimate the parameters of this model. Assuming the expected value of ε_i is 0, ordinary least squares or regression would produce unbiased estimates of these parameters. However, given the limited nature of the dependent variable, these estimates would clearly not be minimum variance. The variance of ε_i is:

$$VAR(\varepsilon_i) = (X_i'\beta)\ (1 - X_i'\beta) \qquad (2)$$

where:

X_i = the vector of input values for the ith student

β = the vector of parameters

which clearly depends on the value of X_i. Homoscedasticity can be restored by redefining our model as:

$$\gamma_i Y_i = \gamma_i X_i'\beta + \gamma_i \varepsilon_i \qquad (3)$$

where:

$$\gamma_i = \frac{1}{X_i'\beta(1 - X_i'\beta)}$$

Estimates of β made by applying least squares regression to this model will be minimum variance, and if the assumptions of the model hold, weighting by γ_i will not change the expected value of the regression coefficients. To estimate the parameters of this modified model, we first obtain an estimate of the parameters of these equations using ordinary least squares. These estimates are then used to estimate γ_i, and each student's input and output measures are multiplied by the appropriate value of γ_i. Minimum variance estimates of β are obtained by applying least squares regression to this modified data.[6]

In addition to these statistical difficulties, the linear additive model precludes the possibility that the productivity of inputs to the educational process depends upon their own level or the level of other inputs. In part, we have attempted to deal with this problem by measuring these inputs in a manner which takes account of certain forms of nonlinearity. For example, by including a variable and the square of that variable as input measures, we examine the possibility that the productivity of that variable depends upon its level. To explore the possibility of other forms of nonlinearity, we

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[6] For a discussion of this method, see J. Johnston, Econometric Methods, pp. 227-228. An alternative approach to the problem of heteroscedasticity, logit analysis, is explained in Appendix B.

have divided the students into subsamples in which the range of specific inputs is restricted. By estimating the parameters of the production function separately for each of these subsamples and comparing these parameters, we examine the extent and magnitude of interaction among the inputs to the educational process.

Measures of Input

In this model, it is assumed that these output measures are functions of three dimensions of input: the time and effort each student brings to the educational process, the quality of the faculty and facilities available to each student at the college attended, and the quality of the other students in the college attended. Each of these dimensions of input is measured by a number of separate variables. The means and standard deviations of these measures for all students and for students in public and private colleges are described in Tables 1 and 2.

The quality of the effort the student brings to the educational process depends upon the quality of the academic skills he has acquired prior to college entry. These skills have been measured for the students in our sample by a battery of ability tests administered about six months prior to college entry. Principal components analysis has been used to measure the separate dimensions of ability reflected in these tests, and the students' scores on these principal components are used as input measures.[7] Preliminary analysis suggested that a number of these components were not related to success in college, and these were dropped from subsequent analyses.[8]

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[7] The high collinearity among the original tests resulted in high standard errors in their estimated effects. Since these principal component scores are orthogonal measures of ability, their separate effects can be measured with precision. For a discussion of principal components analysis, see Donald F. Morrison, Multivariate Statistical Analysis, pp. 221-258.

[8] The results of these preliminary analyses are described in Appendix A.

TABLE 1

Means and Standard Deviations of the Input and Output Measures for the Sample of Students Entering College in 1960

	All Students		Students in Public Colleges		Students in Private Colleges	
	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.
Ability measure 1 (percentiles)	72.06	21.11	70.77	21.48	75.73	19.60
Ability measure 2 "	63.65	24.29	62.01	24.66	68.33	22.60
Ability measure 3 "	49.32	26.95	49.15	26.96	49.79	26.93
Ability measure 4 "	47.22	27.11	47.44	27.05	46.58	27.30
Ability measure 5 "	58.76	28.02	57.39	28.11	62.66	27.39
Ability measure 12 "	43.47	25.73	43.64	25.39	42.97	26.66
Average ability "	72.21	10.70	70.70	9.91	76.47	11.65
Living expenses (hundred dollars)	6.23	4.24	6.02	3.87	6.81	5.09
Working for pay[a]	.506	.500	.504	.500	.513	.499
Hours worked per week for pay	11.68	14.57	11.55	14.46	12.04	14.86
Living at home[a]	.416	.493	.384	.486	.531	.499
Student-faculty ratio	21.12	7.40	20.40	6.46	23.10	9.32
Expend. per student on instruction related activities (hundred dollars)	13.25	5.29	12.52	4.49	15.33	6.65
Expend. per student on org. research and extension (hundred dollars)	8.25	9.75	8.04	9.10	8.83	11.39
Enrollment (thousands)	15.3	10.5	17.5	10.8	9.1	6.4
Enrollment^2	344.3	438.1	421.9	477.1	124.3	158.9
Proportion graduating[a]	.644	.479	.616	.486	.725	.446
Sample size	3,155		2,317		806	

[a] In the analysis, these were dummy variables which took on the value one if the event in question occurred and zero if it did not occur. Their menas and standard deviation reflect the proportion of students for whom the variable took on the value one.

TABLE 2

Means and Standard Deviations of Input and Output Measures for the Sample of Students Entering College in September 1960 and Graduating by November 1965

	All Students		Students in Public Colleges		Students in Private Colleges	
	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.
Ability measure 1 (percentiles)	76.19	18.51	74.85	18.65	79.32	17.86
Ability measure 2 "	67.41	22.57	65.53	23.16	71.93	20.46
Ability measure 3 "	50.38	26.62	50.19	26.67	51.05	26.44
Ability measure 4 "	46.31	26.74	47.05	26.66	44.57	26.83
Ability measure 10 "	30.63	20.76	30.96	20.28	29.82	21.47
Average ability "	73.95	10.64	72.09	9.65	78.31	11.61
Grades	7.88	1.71	7.85	1.69	7.93	1.75
Living at home[a]	.377	.485	.341	.474	.450	.497
Working for pay[a]	.469	.499	.470	.499	.463	.499
Hours worked for pay (per week)	9.11	12.05	9.05	11.83	9.28	12.66
Student-faculty ratio	20.6	7.06	20.4	7.03	21.1	8.41
Expend. per student on instruction related activities (hundred dollars)	13.93	5.62	12.89	4.55	16.36	6.97
Expend. per student on org. research and extension (hundred dollars)	9.30	10.48	8.82	9.44	10.42	12.52
Enrollment (thousand students)	15.6	10.6	18.4	10.8	8.8	6.2
Enrollment^2 " "	354.6	438.4	455.6	480.1	118.9	151.2
Majoring in:						
Math & Physical Science[a]	.254	.436	.261	.439	.239	.427
Social Science & Humanities[a]	.315	.465	.306	.461	.337	.473
Pre-law, Medicine, Dentistry[a]	.013	.111	.012	.110	.014	.116
Engineering[a]	.020	.146	.024	.152	.010	.097
Proportion attending graduate or professional schools[a]	.537	.499	.521	.500	.568	.495
Sample size	2,453		1,717		736	

[a]See Table 1, note a.

At the time the student decides whether or not to attend graduate school, these skills have been altered by the nature of the undergraduate experience. Given the substantial differences in the rate of student development in college, ability at the time of college entrance may be a poor predictor of the student's ability at the time of college graduation. Consequently, in estimating the likelihood of graduate school attendance, the student's grades in college are included as an additional measure of student input to the educational process. These may be viewed as an intermediate output of the educational process which then exerts an effect on the student's desire and ability to gain entrance to graduate school.[9]

In addition to these skills, the quality and quantity of the effort the student brings to the educational process will also depend upon the nature of the student's living environment while in college. About half the students in our sample worked for pay while in college, and those students worked an average of 22 hours per week during the school year. It seems reasonable to suppose that, at least in excess of some reasonable number of hours, working for pay reduces the time the student spends on the educational process. Hence, the model includes as a negative input a variable measuring the number of hours the student worked for pay while in college. In order to take account of the possibility that the adverse effects of working for pay do not begin until the student works in excess of a certain number of hours, we also include a dummy variable which takes on the value one if the student works and zero otherwise.

In addition, the students in our sample varied in the nature of their living environments while in college. About 40% of the students in the

[9] A separate function was used to estimate the relationship between grades and other inputs to the educational process. The parameters of this function are described in Table 5.

sample described in Table 1 lived at home while attending college. While living at home may reduce the financial costs of college attendance, it may also reduce the input to the student's college program by limiting his contact with the informal education process which takes place among those students who lived at school. To reflect this possibility, we include in this model a variable which takes on the value one if the student lives at home while in college and is zero otherwise.

Students also differ in the amount they spend on their living accommodations while in college. While the average student in our sample reported spending about $600 per year on room, board, and other college expenses, 13.2% spent $1,000 or more per year, and 31% spent less than $300. These differences reflect the fact that a student may reduce his living expenditures by substituting time for money in structuring his living environment, or by reducing the quality of that environment. However, these adjustments are likely to reduce either the quantity of the quality of the effort the student brings to the educational process. Thus, by living in overcrowded or dilapidated housing, the costs of college attendance are reduced, but this may deprive the student of an adequate place to study or to relax from studying. The extent of this relationship is explored by examining the relationship between annual living expenditures and the rate of college graduation. This variable was initially included as an input in estimating the probability of graduate school attendance. However, its effect was small and not statistically significant and was dropped from that model.

The second dimension of input examined in this study reflects the quantity and quality of the instructional facilities available at the college attended by each of the students in the sample. These resources are measured by the level of current expenditure per pupil at these colleges, and these expenditures are separated into three components. First, expenditures which have been specifically earmarked for organized research and other noninstructional activities have been separated from all other expenditures. Thus, while there may be important complementarities between research and teaching, it seems reasonable to suppose that research expenditures will have less effect on the quality of the instructional process than other components of expenditure. Moreover, to the extent that research and teaching are competitors for faculty time and facilities, increasing research expenditure may actually diminish the output of the instructional process.

The remaining expenditures, which include expenditures for faculty and other personnel, library expenditures, and expenditures for the maintenance of buildings and equipment, were separated into two components. First, these expenditures were adjusted to reflect the level which would have prevailed at a student-faculty ratio of 20:1 .[10] The actual student-faculty ratio is included as a separate input measure. The student-faculty ratio has been separated from other instructional facilities for two reasons. Its effect, if any, is reasonably easy to interpret. If reducing this ratio increases either the rate of graduation or graduate school attendance, this

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[10]This estimate was computed as follows:

$$IE^*_i = IE_i + FE_i \frac{IE_i}{TE_i} \left(\frac{SIF_i}{20} - 1\right)$$

where:

IE^*_i = instruction-related expenditures which would prevail at the ith college if that college had a student-faculty ratio of 20: 1

IE_i = actual instruction-related expenditure at the ith college

FE_i = total expenditures on faculty at the ith college

S/F_i = the ratio of faculty to students at the ith college

TE = total expenditures at the ith college .

would suggest that reducing class size or otherwise increasing student-faculty contact increases the output of the educational process. The data available on the other components of instructional expenditure is already too highly aggregated to clearly interpret the policy implications of its effect on output. On the other hand, other studies of the educational process suggest that reducing class size has little or no effect on the output of the educational process. If this is the case, we do not wish to obscure the effects of other components of expenditures by combining them in a single expenditure measure which would be heavily influenced by the student-faculty ratio.

While the above resources were measured on a per-student basis, it does not seem reasonable to suppose that the quality of these resources increases linearly with the level of expenditure per pupil. For example, it probably costs less per student to maintain an adequate library in a large than in a small school. On the other hand, beyond a certain size, further increases in the size of the student population may produce an impersonality which is deleterious to the educational process. In order to measure these economies and diseconomies of scale, we have included both enrollment and the square of enrollment as inputs to the educational process.

The quality of a college may depend not only on the quality of its facilities but the quality of the student body. Students clearly learn from each other as well as their instructors, and moreover, the quality of the student body influences the level of instruction which is possible. Consequently, as a third dimension of input, we have included a measure of the average ability level of the students at each of the colleges in this sample. This is measured by the mean score on the first principal component of ability of the students in the Talent sample attending each of these colleges. Since the Project Talent sample from which these students are drawn is roughly representative of the high-school population, the students in this sample at each college are roughly representative of the student body at those colleges.[11]

In estimating the relationship between these inputs and the rate of graduate school attendance, we also attempt to control for the student's choice of undergraduate major. Other studies have shown that students in some fields are much more likely to go on to graduate school than others. Since these fields of study may also vary in the ability level of the students they attract, it is necessary to control for this choice in order to avoid biasing the effect of other variables. Undergraduate majors have been grouped into four categories -- mathematics and the physical sciences, the social sciences and humanities, engineering, and professional fields requiring postgraduate training (law, medicine, dentistry, etc.), -- and dummy variables are used to reflect the student's presence in each of these categories. Students not included in any of these majors were recorded as zero on all four of these variables.

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[11] As noted previously, colleges attended by less than ten students from the Project Talent sample were excluded from this analysis. Assuming a normal distribution of ability scores at each college and viewing the samples of students at each college as if they were drawn randomly from the population of students at each college, the probability of our estimate being more than four percentiles from the true college mean would be less than .05 . Of course, since the Talent data was gathered from a stratified, random sample of schools and a cluster sample of students, the actual variance of sample means might be little larger or smaller than that estimated from this data. However, since 80% of the variance in ability test scores occurs within rather than between high schools, the effect of cluster sampling on the distribution of ability scores is quite modest. The precise effect of stratification is unclear.

IV. EMPIRICAL RESULTS

The Linear Model

Tables 3 and 4 describe the estimated parameters relating each input measure to the rates of graduation and graduate school attendance respectively. In each case, the regression coefficients described in these tables have been scaled to reflect the effect of a unit change in each of the inputs on the number of graduates (graduate school attenders) per 100 entrants (graduates). Consequently, unit changes in these output measures are referred to as changes of 1 percentage point in the rate of graduation or graduate school attendance.

The results of these tables indicate that the quality and quantity of the effort the student brings to the educational process have pronounced effects on the student's likelihood of graduation and graduate school attendance. Considering the rate of graduation first, we note that each of the six components of ability examined has a statistically significant effect on this output measure. A 10 percentile increase in the first of these components would appear to result in a 4.5 percentage point increase in the graduation rate, while a 10 percentile increase in the second component would increase the graduation rate by 3.1 percentage points. The significance of these magnitudes becomes apparent if they are used to examine the probable graduation rate of students currently not attending college. Students not attending college in 1960 have ability scores 42 percentiles lower on the first ability measure and 23 percentiles lower on the second than those attending. As a result of this difference, if they were to attend college, these students would have a graduation rate 25 percentage

TABLE 3

Regression Coefficients Relating Measures of Educational Input[a] to the Relative Frequency With Which Entrants Graduate from College

	All Schools			Public Schools			Private Schools		
	Reg. Coef.	Stand. Error	Sig.[b] Level	Reg. Coef.	Stand. Error	Sig.[b] Level	Reg. Coef.	Stand. Error	Sig.[b] Level
Constant	-11.08	7.49	.141	-15.44	9.04	.087	7.62	18.49	.681
Ability measure 1	.449	.045	.000+	.442	.052	.000+	.448	.097	.000+
Ability measure 2	.307	.036	.000+	.294	.042	.000+	.336	.070	.000+
Ability measure 3	.105	.030	.000+	.127	.036	.000+	.065	.051	.204
Ability measure 4	.079	.032	.013	.115	.039	.003	.004	.057	.944
Ability measure 5	.103	.034	.002	.130	.041	.002	.015	.063	.810
Ability measure 12	.121	.033	.000+	.092	.041	.025	.147	.058	.012
Average ability	.128	.097	.187	.229	.124	.066	.021	.197	.912
Living expenses	.220	.190	.250	.340	.250	.183	-.090	.300	.757
Work/not work	19.07	2.16	.000+	18.41	2.67	.000+	17.48	3.87	.000+
Hours worked per week	-1.16	.074	.000+	-1.10	.086	.000+	-1.18	.154	.000+
Live at home/at school	-4.08	1.76	.021	-5.72	2.15	.008	.489	3.27	.880
Student/faculty ratio	-.045	.115	.697	-.027	.165	.873	-.396	.217	.068
Expend. per student on instruction rel. activities	-.200	.210	.332	-.630	.290	.031	-.610	.480	.200
Expend. per student on org. research & extension	.220	.100	.030	.230	.120	.066	.320	.230	.167
Enrollment	.028	.244	.912	-.150	.361	.674	3.57	.916	.000+
Enrollment^2	-.003	.006	.667	.003	.008	.704	-.140	.038	.000+
R^2	.468			.325			.667		
F	159.50			64.73			91.48		
N	3,089			2,297			792		
Efficiency ratio[c]	.967			.971			.966		

[a]The means and standard deviations of these input measures are described in Table 1. The regression coefficients reflect the change in the percent of entrants graduating for a unit change in each input. Ability is measured in percentiles and all expenditures are in hundreds of dollars. Enrollment is measured in thousands.

[b]Probability of observing a coefficient this far from zero, if that were the true value of this parameter.

[c]The ratio of the standard error of estimate after correcting for heteroscedasticity to the standard error of estimate before this correction was made.

TABLE 4

Regression Coefficients Relating Measures of Educational Input[a] to the Relative Frequency with Which College Graduates Attend Graduate and Professional Schools

	All Schools			Public Schools			Private Schools		
	Reg. Coef.	Stand. Error	Sig.[b] Level	Reg. Coef.	Stand. Error	Sig.[b] Level	Reg. Coef.	Stand. Error	Sig.[b] Level
Constant	-70.12	10.09	.000+	-87.49	11.26	.000+	-13.58	28.29	.631
Ability measure 1	.116	.078	.139	.076	.087	.384	.209	.166	.207
Ability measure 2	.165	.045	.000+	.185	.052	.000+	.178	.092	.052
Ability measure 3	.046	.035	.187	-.048	.040	.234	.263	.066	.000+
Ability measure 4	-.017	.037	.660	.057	.044	.186	-.127	.071	.073
Ability measure 10	.083	.059	.152	.181	.068	.008	-.091	.113	.424
Average ability	.151	.127	.234	-.034	.154	.825	-.089	.285	.757
Grades in college	5.64	.514	.000+	8.29	.670	.000+	2.11	.817	.010
Work/not work	10.63	2.88	.002	10.39	3.36	.002	7.89	5.49	.152
Hours worked	-.723	.112	.000+	-.618	.130	.000+	-.826	.218	.000+
Live at home/at school	6.16	1.98	.000+	6.63	2.32	.004	3.58	3.92	.362
Student/faculty ratio	.772	.165	.000+	.928	.211	.000+	.417	.340	.222
Expend. per student on instruction rel. activities	1.150	.270	.000+	1.740	.360	.000+	.040	.670	.960
Expend per student on org. research & extension	-.010	.140	.920	.040	.160	.794	.340	.310	.267
En Enrollment	.949	.319	.003	.827	.476	.084	3.16	1.14	.006
$Enrollment^2$	-.022	.008	.005	-.022	.010	.032	-.128	.047	.007
College major									
Math & Phys. Sci.	12.61	2.36	.000+	9.77	2.74	.000+	14.31	4.45	.001
Soc. Sci. & Human.	5.45	2.22	.014	5.26	2.59	.042	.116	4.19	.984
Pre-law, Med., & Dent.	13.96	7.76	.073	24.58	9.20	.008	-7.72	14.16	.589
Engineering	6.84	7.02	.332	7.33	7.48	.327	8.50	17.49	.624
R^2	.320			.359			.306		
F	56.79			47.19			15.67		
N	2,433			1,705			728		
Efficiency ratio[c]	.982			.962			1.000		

[a]The means and standard deviations of these input measures are described in Table 2. The regression coefficients reflect the change in the percent of entrants graduating for a unit change in each input. Ability is measured in percentiles and all expenditures are in hundreds of dollars. Enrollment is measured in thousands.

[b]See Table 3, note b.

points lower than the average student currently enrolled.

Examining the effect of these ability measures on the rate of graduate school attendance involves estimating both the direct effect of these inputs and any indirect effects which ability exerts on graduate school attendance through its effect on grades in college. In order to determine these indirect effects, the relationship between these test scores and grades in college are estimated in Table 5. Including both direct and indirect effects, a 10 percentile increase in these ability measures would increase the rate of graduate school attendance by 2.5 percentage points in the case of ability measure one and 1.9 percentage points in the case of ability measure two. The effects of the other ability measures examined, both direct and indirect, are quite modest.

The amount of time the student spends working for pay while in college also appears to adversely affect his chances of graduation and graduate school attendance. In the case of graduation, this adverse effect does not begin unless the student works in excess of 16 hours per week. However, each hour worked in excess of 16 reduces the rate of graduate school attendance by nearly 1.2 percentage points. In the case of graduate school attendance, the adverse effects of working for pay begin after 14 hours per week and reduce the rate of graduation by .8 percentage points per hour worked.

The impact of other components of the student's living environment in college is less straightforward. Living expenditure, which is not included in the equation estimating the rate of graduate school attendance, has a quite modest positive effect on the rate of graduation, and the high standard error of estimate makes it difficult to generalize about the effect of this variable. Living at home has a pronounced effect both on gradua-

TABLE 5

Regression Coefficients Relating[a] Grades in College to Measures of Input[a] to the Educational Process

	Var. Mean	Reg. Coef.	Stand. Error	Signif.[b] Level
Constant	1.0	5.47	.574	.000+
Ability measure 1	76.3	.025	.002	.000+
Ability measure 2	67.4	.005	.002	.009
Ability measure 3	50.6	.007	.001	.000+
Ability measure 4	53.7	.000+	.002	.865
Ability measure 5	62.0	-.003	.002	.037
Average ability 1	73.2	-.006	.006	.337
Average ability 2	63.5	-.009	.004	.042
Average ability 3	51.8	-.002	.005	.631
Average ability 4	51.1	-.011	.005	.028
Work/not work	.472	.077	.117	.515
Hours worked	9.21	-.011	.004	.030
R^2	.118			
F	13.59			
N	2,245			

[a]Grades are measured on a twelve-point scale from D- to A+.

[b]See Table 3, note b.

tion and graduate school attendance but in opposite directions. The student who lives at home has a graduation rate 4.1 percentage points lower, and (if he does graduate), a rate of graduate school attendance 6.2 percentage points higher than a similar student who lives at home. There are several plausible explanations for the apparent inconsistency in the effect of this variable. Other analyses of this data which we have conducted suggest that the adverse effects of living at home occur primarily for low-ability students. Consequently, the average ability of college graduates who live at home may be greater than that of graduates who lived at school. This would explain the positive relationship between living at home and graduate school attendance. Moreover, since living at home reduces the costs of college attendance, students who live at home may be able to finance the costs of graduate school attendance more easily than students from similar backgrounds who live at school.

In examining the effect of college characteristics, we find sharp differences between the effect of these measures on the rates of graduation and graduate school attendance. Of these measures, only research expenditures has a statistically significant effect on the graduation rate, and its effect is so modest -- each $100 increase in research expenditures results in a .2 percentage point increase in the graduation rate -- that it may be ignored. Increasing the average ability level of other students and reducing the student-faculty ratio, both have positive effects on the graduation rate, but these effects are not statistically significant. While the effect of increasing instructional expenditures is also not statistically significant, it has an unexpected sign. Altering the enrollment level had little or no effect on the graduation rate.

The rate at which graduates attend graduate and professional schools appears sensitive to changes in the level of instructional expenditures per student. Each $100 increase in this component of input raises the rate of graduate school attendance by 1.2 percentage points. Since the colleges in our sample range from those spending as little as $350 to those spending nearly $4,000 on these inputs, the importance of this measure of college quality in explaining variations in the rate of graduate school attendance is substantial. Neither research expenditure nor average student ability have either large or statistically significant effects on the rate of graduate school attendance. On the other hand, the effect of varying the student-faculty ratio is substantial, significant, and has an unexpected sign. Thus, this model suggests that reducing the student-faculty ratio from 30:1 to 20:1 reduces the rate of graduate school attendance by nearly 7.7 percentage points.

It should also be noted that altering the enrollment level, while it has no effect on the rate of graduation, does affect the rate of graduate school attendance. This effect is nonlinear. Increasing enrollment from 5,000 to 10,000 students increases the rate of graduate attendance by 2.3 percentage points; an increase from 10,000 to 15,000 students results in an increase of 1.4 percentage points; and an increase from 13,000 to 20,000 students increases this rate by only .3 percentage points. Increasing enrollment beyond 20,000 students appears to reduce the rate of graduate school attendance.

While these estimates provide some useful insights into the workings of the educational process, several of these results call into question the plausibility of this framework for evaluating the educational process. First, the estimated parameters of these equations suggest that none of the college characteristics examined has any significant effect on the rate of graduation. Secondly, the model suggests that decreasing the student-faculty ratio would reduce the rate of graduate school attendance. If these conclusions are allowed to stand, either the graduation rate and the rate of graduate school attendance are inappropriate measures of output, or the production model used in this study is an unreasonable description of the educational process. Several alternative explanations of these results are explored below.

Public and Private Colleges Compared

As we suggest at the outset, degree standards may vary from institution to institution. If colleges with high levels of expenditure per student also impose high degree standards, this may obscure any positive relationship which would exist between the components of expenditure per student and the graduation rate, holding degree standards constant. The relationship between degree standards and expenditure per student is less likely to obscure the relationship between these expenditures and the graduation rate in private than in public colleges. This is true because private colleges can raise degree standards without altering the graduation rate by raising admission requirements. In contrast, public colleges are often precluded by law from altering admission standards, and consequently, raising degree standards in public colleges would tend to reduce the graduation rate. To explore this possibility, we have estimated the parameters of the college production function for public and private colleges separately.

Examining the parameters of the production function estimated for students attending private colleges, we find that reducing the student-faculty ratio from 30:1 to 20:1 appears to increase the graduation rate by nearly

4.0 percentage points, and this effect is significant at the .07 level. While increasing instructional expenditures continues to have an unexpected sign, the effect of this variable is not statistically significant. On the other hand, in public colleges, reducing the student-faculty ratio has no effect on the graduation rate, and increasing instructional expenditures reduces the graduation rate by .6 percentage points per $100 of expenditure. The effect is significant at the .03 level. Two important conclusions emerge from these comparisons. First, at least under certain circumstances, one component of expenditure per student--the student-faculty ratio--has a significant and appreciable effect on the graduation rate in the expected direction. Secondly, the relationship between degree standards and expenditures provides a plausible explanation of the failure to observe a significant relationship between expenditures and the graduation rate for the sample as a whole.

Several other differences which emerge between public and private colleges are also worthy of note. The enrollment level, which has no significant effect on the rate of graduation in public colleges, is significant in private colleges. Increasing enrollment appears to increase the graduation rate until enrollment reaches 12.7 thousand students, but further increases in enrollment diminish this output. As an illustration of the magnitude of this effect, an increase in enrollment from 5,000 to 10,000 students would increase the graduation rate by nearly 7.0 percentage points. Secondly, while in public colleges increasing the average ability of other students appears to increase each student's chances of graduation, this is not the case in private colleges. Finally, the adverse effects of living at home while in college appear to occur only in the case of students attending public colleges.

There appears to be a fairly wide difference between otherwise comparable public and private colleges in their rates of graduation. The model suggests that a public college whose input level was the average for the sample of all colleges would have a graduation rate nearly 11 percentage points higher than a similar public college. Given the differences in the effect of specific variables between public and private colleges, the magnitude of this differential depends upon the input level at which the comparison is made. The difference is wider for students who live at home than for those who live at school and narrower in colleges where enrollment is less than 5,000 students or greater than 20,000 than for colleges of average size (15,000). Since increasing the student-faculty ratio has an effect in private but not in public colleges, this differential is also narrower in colleges where this ratio is high. Since public and private colleges differ widely with respect to the student-faculty ratio, enrollment, and the percent of students living at home, it is difficult to determine whether differences in the graduation rate between public and private colleges reflect nonlinearities in the effect of these variables or structural differences between public and private colleges.

The greater homogeneity of the student body within private colleges suggests one possible explanation for this difference. At every ability level, there appears to be less variation in ability within private colleges than within public colleges. Consequently, if the same degree standards were applied at public and private colleges where the average ability of students was the same, more students would fail to meet those standards at the public than at the private colleges. This suggests that developing a more differentiated public college system, in which students of different ability levels attended different colleges, would reduce the rate of attrition in public colleges.

We also have estimated separately for students in public and private colleges the parameters of the model relating educational inputs to the rate of graduate school attendance. (See Table 4.) Once again, there are sharp differences in these parameters between public and private colleges particularly with respect to the components of expenditure per pupil. Increasing instructional expenditures per pupil has a pronounced effect on the rate of graduate school attendance in public schools--each $100 increase in these expenditures increases the rate of graduate school attendance by 1.7 percentage points--but little or no effect in private colleges. This is true for a number of other variables as well, and in general, the model is less successful in relating the rate of graduate school attendance to these inputs in private than in public colleges. In part, this may reflect the fact that our sample consisted of relatively few students in private colleges, and the inputs for private colleges are substantially more collinear than those for public colleges. Alternatively, graduate school attendance may simply be a less valid measure of output for students attending private than for those attending public colleges.

Nonlinearities

It also seems possible that some of the anomalies in the estimated effects of the inputs to the educational process reflect nonlinearities in the relationship between these inputs and outputs. To explore this possibility, we have estimated the parameters of this model separately for subsamples in which the range of specific inputs is restricted. In estimating the parameters of the model for these subsamples, however, no effort was made to adjust for heteroscedasticity. Moreover, when the range of specific inputs to this model is restricted, this also alters the average level of other input measures. Consequently, it is not possible to use this approach to establish with precision the impact of altering the level of specific inputs. Nevertheless, these comparisons are suggestive of certain patterns of interaction. The most revealing of these comparisons are described in Tables 6, 7, and 8.

In Table 6, the relationship between these inputs and the rate of graduation is examined for students attending colleges where the student-faculty ratio was less than or equal to 20:1 and those attending colleges where this ratio was greater than 20:1. It should be noted that the colleges where the student-faculty ratio is low may also be described as high input in other respects as well. The students in these colleges score higher on ability tests and are less likely to work for pay while in college than those attending colleges where the student-faculty ratio is high. These colleges also spend more on both instruction and research-related activities than those with high student-faculty ratios. The most striking result to emerge from Table 6 is the difference in the apparent effect of the student-faculty ratio between these two subsamples. In schools where the student-faculty ratio was in excess of 20:1, each unit reduction in this ratio appears to <u>increase</u> the graduation rate by .4 percentage points. In schools where the student-faculty ratio was below 20:1, each unit reduction appears to <u>reduce</u> the graduation rate by 1.0 percentage points. Both of these effects are significant at the .05 level. This apparently "U-shaped" effect of reducing the student-faculty ratio provides an alternative explanation for the failure to discern a significant relationship in the sample of all students.

It is also interesting to note that a number of other input measures

TABLE 6

Regression Coefficients Relating Measures of Educational Input to the Relative Frequency with Which Entrants Receive College Degrees in Colleges with Varying Student-Faculty Ratios[a]

	Colleges where the student-faculty ratio is:							
	Less than or equal to 20:1				Greater than 20:1			
	Mean	Reg. Coef.	Stand. Error	Sig.[b] Level	Mean	Reg. Coef.	Stand. Error	Sig.[b] Level
Constant	1.0	-48.7	14.8	.000+	1.0	-16.0	10.6	.131
Ability measure 1	75.4	.482	.073	.000+	69.5	.397	.061	.000+
Ability measure 2	63.8	.249	.056	.000+	63.6	.312	.048	.000+
Ability measure 3	50.5	.161	.045	.000+	48.4	.111	.043	.010
Ability measure 4	47.1	.133	.049	.007	47.3	.114	.046	.014
Ability measure 5	60.0	.118	.053	.025	57.8	.129	.049	.009
Ability measure 12	42.1	.076	.052	.144	44.5	.125	.047	.009
Average ability	75.9	.463	.155	.003	69.5	.254	.152	.095
Living expenses	6.97	.340	.260	.193	5.67	.800	.280	.004
Work/not work	.451	16.75	3.53	.000+	.548	19.6	3.61	.000+
Hours worked	9.2	-1.21	.136	.000+	13.5	-1.11	.119	.000+
Student-faculty ratio	14.5	1.02	.394	.010	26.0	-.412	.204	.044
Expend. per student on instruction related activities	15.25	-.300	.270	.257	11.76	.070	.530	.897
Expend. per student on research and extension	13.79	.160	.130	.226	4.09	.060	.370	.873
Enrollment	13.6	-.823	.535	.126	16.6	-.284	.398	.478
Enrollment[2]	258.3	.028	.015	.057	408.8	.002	.008	.841
R^2	.216				.163			
F	24.54				23.30			
N	1,351				1,804			

[a]An F statistic testing the hypothesis that the slope coefficients of these two regressions are the same was 1.88 with 15 and 3,125 degrees of freedom. This is significant at the 5% level.

[b]See Table 3, note b.

TABLE 7

Regression Coefficients Relating Measures of Educational Input to the Relative Frequency with Which College Graduates Attend Graduate and Professional Schools from Colleges with Varying Levels of Instructional Expenditure per Pupil[a]

	Students attending colleges where instructional expenditure per student is:							
	Greater than $1,200				Less than or equal to $1,200			
	Var. Mean	Reg. Coef.	Stand. Error	Sig.[b] Level	Var. Mean	Reg. Coef.	Stand. Error	Sig.[b] Level
Constant	1.0	-88.3	18.6	.000+	1.0	-86.5	15.8	.000+
Ability measure 1	80.7	.021	.115	.857	71.1	.099	.106	.352
Ability measure 2	70.5	.193	.067	.004	64.0	.176	.064	.006
Ability measure 3	50.4	.046	.050	.362	50.4	-.019	.052	.711
Ability measure 4	45.8	.082	.054	.129	46.8	-.016	.055	.771
Ability measure 10	28.0	.055	.085	.515	33.6	.093	.083	.256
Average ability	79.4	.4[illegible]	.214	.054	67.7	.185	.183	.312
Grades in college	8.02	6.25	.766	.000+	7.71	8.74	.885	.000+
Living at home/at school	.345	6.17	2.87	.032	.414	1.26	2.98	.674
Work/not work	.449	5.56	4.49	.219	.491	8.83	4.49	.050
Hours worked per week	8.20	-.676	.203	.000+	10.14	-.536	.175	.002
Student-faculty ratio	18.6	.583	.253	.021	22.9	.247	.254	.332
Expend. per student on instruction rel. activities	17.81	1.021	.400	.010	9.55	2.16	1.080	.044
Expend. per student on research and extension	14.42	.100	.160	.509	3.54	-1.42	.410	.000+
Enrollment	18.9	.858	.453	.060	11.8	1.27	.565	.025
Enrollment^2	488.0	-.018	.010	.082	203.9	-.032	.015	.033
College major								
Math & Phys. Sci.	.274	10.2	3.29	.002	.232	13.9	3.59	.000+
Soc. Sci. & Human.	.304	5.48	3.14	.082	.328	1.89	3.25	.562
Pre-law, medicine, dentistry	.017	24.8	10.14	.015	.008	-15.5	15.54	.322
Engineering	.024	-1.00	8.54	.914	.016	28.3	11.22	.012
R^2	.137				.170			
F	10.83				12.27			
N	1,306				1,158			

[a] An F statistic testing the hypothesis that the slope coefficients of these two regressions are the same was 2.10 with 20 and 2,424 degrees of freedom. This is significant at the 1% level.

[b] See Table 3, note b.

TABLE 8

Regression Coefficients Relating Measures of Educational Input to the Relative Frequency with which College Graduates Attend Graduate and Professional Schools from Colleges with Varying Levels of Research Expenditure per Pupil[a]

	Students attending colleges where expenditure per student on research and extension is:							
	Greater than $1,000				Less than or equal to $1,000			
	Var. Mean	Reg. Coef.	Stand. Error	Sig.[b] Level	Var. Mean	Reg. Coef.	Stand. Error	Sig.[b] Level
Constant	1.0	-83.4	21.1	.000+	1.0	-74.0	13.5	.000+
Ability measure 1	80.5	-.038	.131	.772	73.3	.104	.097	.280
Ability measure 2	69.0	.178	.076	.019	66.3	.194	.059	.000+
Ability measure 3	52.8	.066	.058	.256	48.8	-.017	.047	.711
Ability measure 4	46.1	.054	.063	.395	46.4	.011	.049	.818
Ability measure 10	26.3	.019	.099	.841	33.5	.091	.075	.222
Average ability	79.2	.435	.242	.072	70.5	.193	.164	.242
Grades in college	8.04	6.69	.863	.000+	7.77	7.66	.781	.000+
Living at home/at school	.255	5.93	3.37	.078	.459	1.39	2.66	.603
Work/not work	.417	4.56	5.09	.368	.503	8.78	4.10	.032
Hours worked per week	7.0	-.677	.249	.007	10.5	-.587	.159	.000+
Student-faculty ratio	16.3	.147	.358	.682	23.5	.266	.236	.256
Expend. per student on instruction rel. activities	18.05	1.110	.410	.006	11.18	1.372	.490	.005
Expend. per student on research and extension	19.00	.300	.180	.093	2.83	-1.50	.630	.016
Enrollment	18.3	.242	.537	.653	13.7	1.15	.475	.015
$Enrollment^2$	459.4	-.001	.012	.912	284.6	-.023	.012	.061
College major:								
Math & Phys. Sci.	.294	8.51	3.61	.019	.228	14.69	3.26	.000+
Soc. Sci. & Human.	.274	9.52	3.71	.010	.343	.374	2.86	.897
Pre-law, Medicine, dentistry	.015	16.23	11.99	.177	.011	12.51	11.89	.294
Engineering	.030	3.52	8.63	.682	.013	22.73	10.96	.038
R^2	.188				.150			
F	11.83				13.60			
N	986				1,478			

[a] An F statistic testing the hypothesis that the slope coefficients of these two regressions are the same was 2.04 with 20 and 2,424 degrees of freedom. This is significant at the 1% level.

[b] See Table 3, note b.

appear to be complements of the student-faculty ratio.[12] Thus, the adverse effects of working for pay while in college begin after fewer hours of work and more severly affect the rate of graduation in colleges with low than in colleges with high student-faculty ratios. Moreover, increasing the average ability level of the student population has a greater effect on the graduation rate in colleges where the student-faculty ratio is low than in those where it is high. On the other hand, living expenditures and the other inputs to the educational process appear to be substitutes. In low input colleges, each $100 increase in these expenditures increases the graduation rate by .8 percentage points. This effect is more modest and not statistically significant in the high input subsample.[13]

In Tables 7 and 8, we examine the parameters of the model relating these inputs to the rate of graduate school attendance. In Table 7, the sample has been divided into students attending schools spending in excess of $1,200 per year and those attending schools spending less than this amount. Four results of importance emerge from examining the relation between inputs and outputs for these two subsamples. First, as the level of expenditure per student increases, the effect of this variable appears to diminish: a $100 increase in instructional expenditures in schools spending less than $1,200 per student increases the rate of graduate school attendance by 2.2 percentage points; in colleges spending

[12] The increase in the productivity of these inputs may also be attributed to complementarity with other components of input. Thus, similar interaction was observed when the sample was divided with respect to the ability level of the students. If the marginal product of these variables increased as their level increased, this would also account for the difference in the regression coefficients between these subsamples. Other comparisons suggest that this last possibility was unlikely.

[13] The reduction in the effect of living expenses between these two subsamples may also reflect diminishing returns to successive increases in the level of this variable.

in excess of $1,200, a $100 increase in expenditures increases the rate of graduate school attendance by only 1.0 percentage points.

Secondly, the effect of reducing the student-faculty ratio, while it continues to have an unexpected sign, is substantially smaller in both of these subsamples than in the sample as a whole. This suggests a possible explanation for the effect of this variable. The student-faculty ratio is inversely related to instructional expenditures, and the effect of instructional expenditures increases. The apparently adverse effect of decreasing the student-faculty ratio may, in part, reflect these nonlinearities in the effect of instructional expenditures.

Thirdly, as is the case when the graduation rate is the output measure, the effects of increasing average ability and diminishing the number of hours worked for pay are greater in high than in low input colleges. For students in schools spending over $1,200, increasing the average ability of other students by 10 percentiles increases the rate of graduate school attendance by 4.1 percentage points, and this effect is significant at the .05 level. In colleges spending less than $1,200, this increase would affect a 1.9 percentage point increase in the rate of graduate school attendance, and this effect is significant only at the .31 level. The adverse effects of working for pay while in college begin after 8.2 hours per week in colleges spending over $1,200, but in schools spending less than $1,200, this effect does not begin until the student works in excess of 16 hours. Moreover, in the high-input colleges, each hour worked reduces the rate of graduate school attendance by .68 percentage points. This reduction is .54 percentage points per hour worked in low-input colleges.

There is, finally, a rather striking difference evidenced in this table between low and high-input schools in the impact of research expenditures. In schools spending less than $1,200 per student on instruction-related activities, each $100 increase in research expenditures appears to reduce the rate of graduate school attendance by 1.4 percentage points, and this effect is statistically significant at the .001 level. In schools spending over $1,200, the level of research expenditures has little or no effect on the rate of graduate school attendance. Of course, it is unclear whether the difference between these two subsamples in the effect of research expenditures results from the variation in the level of instructional expenditures, the level of research expenditures, or some other difference between these two subsamples. Thus, we find a similar difference in the effect of this variable between the two subsamples examined in Table 8. In this table, the students have been divided into those attending schools spending less than $1,000 on research and extension activities and those spending in excess of this amount. However, it seems reasonable to infer from these results that in schools where inputs are generally in short supply--either because instructional expenditures are low, or because student quality is low, or because research expenditures are low--research competes with instruction for available resources with the result that increasing research expenditures diminishes the output of the instructional process. On the other hand, in resource-rich schools, the expansion of research activities has no deleterious effects on the instructional process, and there may even be positive spillover from research to instruction.

The negative impact of research expenditures suggests another factor contributing to the apparently adverse effect on the rate of graduate school attendance of reducing the student-faculty ratio. In measuring the student-faculty ratio, no effort was made to distinguish between faculty involved in the program of resident instruction and those involved primarily in research or extension activities. If the level of research expenditure per student is inversely related to the rate of graduate school attendance, and if schools with low student-faculty ratios are those in which a substantial component of faculty time is devoted to research, this may account for the adverse effect on the rate of graduate school attendance of reducing the student-faculty ratio. This explanation receives some support from the results of Table 8. Controlling for the level of research expenditures further reduces the effect of alterations in the student-faculty ratio, and the effect of reducing the student-faculty ratio is more adverse in the subsample in which research expenditures have a negative effect on the rate of graduate school attendance than in the subsample in which research expenditures have no effect.

V. CONCLUSIONS

The estimated parameters of this model have implications for both public and private educational decisions. First, for the student deciding whether or not to attend college, the model suggests that the success of this investment depends heavily on the student's ability level and the financial capital available to him for this investment. Students whose ability level is low or who, because of inadequate financing, must work for pay while they are in college, are substantially less likely to graduate or to attend graduate school than those with adequate financing and pre-college training. Living at home to reduce the costs of college attendance also reduces the student's likelihood of college graduation. A student attending the average college in our sample who scored in the 90th percentile in each of the first two ability measures, who lived at school, and did not work for pay while in college, would have a probability of graduation of .860, and if he does graduate, a probability of graduate school attendance of .501. A student attending the same college who scored in the 30th percentile on each of these ability measures, who lived at home, and who worked 25 hours per week for pay while in college, would have a .251 probability of graduation, and if he did graduate, a .178 probability of attending graduate school. If the probabilities of graduation and graduate school attendance are important determinants of the attractiveness to students of college attendance, these relationships help to explain the positive association of the rate of college attendance with both ability and family income.

The model also provides some guides for the student choosing among alternative colleges. Among private colleges and colleges where the student-faculty ratio is in excess of 20:1, attending colleges where the student-faculty ratio is low increases the student's likelihood of college graduation. For students interested in graduate study, these data suggest that there are advantages in choosing a college which has a high level of instructional expenditure per pupil and in which the enrollment level is relatively high. The impact of increasing enrollment diminishes as enrollment increases and reaches an optimum at 20,000 for public colleges and 12,500 for private colleges. For students of high ability or among colleges where expenditure per student is high, the likelihood of both graduation and graduate school attendance can be increased by choosing colleges where average ability is high.

These prescriptions may also be interpreted as guides for college administrators concerned with reducing the rate of student attrition or increasing the rate of graduate school attendance. Thus, colleges in which the student-faculty ratio is currently in excess of 20:1 could diminish student attrition by reducing this ratio. By increasing instructional expenditures, the model suggests that these colleges could increase the rate at which their graduates attend graduate and professional schools.

The implications of the model with respect to average ability of the student body are of particular interest. In colleges where the level of expenditure per student is high, increasing the average ability level of the student body increases each student's chances of graduation and graduate school attendance. Thus, offering scholarships as inducements to high ability students may represent a reasonable investment in the quality of the undergraduate program.

Finally, the model may be viewed as a guide to public educational policy. One apparent objective of public investment in education is to assure a more egalitarian distribution of educational output. The model suggests the improving the quality of the capital market for students investing in education might improve the educational opportunities of low-income students. To the extent low-income students attend college, they keep the cost of this investment low by living at home, by working for pay, by living in low-quality housing, or by attending low-input colleges which charge low tuition levels. However, these reductions in input also reduce these students' chances of graduation and graduate school attendance. Greater availability of loans might encourage these students to increase the size of their investment and thereby improve the quality of their output.

In addition to financial constraints, low-income students are also handicapped in college by low-ability levels. Reducing the correlation between ability and income by redistributing investment in primary and secondary schools would also produce a more egalitarian distribution of college outputs. Alternatively, the inputs to the college process could be redistributed in favor of low-income (low-ability) students. The difference in the rates of graduation and graduate school attendance between high and low-income students could be narrowed by increasing the level of instructional expenditure per student and reducing the student-faculty ratio in schools attended by low-income students. Sending low-income students to colleges where average ability (and family income) is high might also increase their chances of graduation and graduate school attendance. However, these two forms of redistribution differ in their implications for the average level of college output. Since the schools currently attended by low-income students tend to have low levels of expenditure per student, and since the components of expenditure appear to exhibit diminishing returns, increasing expenditures in these schools would have a greater return than a similar increase in schools which currently have high levels of expenditure per pupil. On the other hand, there was some evidence that the effect of increasing average ability was greatest in high-input schools. Thus, it may be that increasing average ability has greater effects on high than on low-ability students. If this were the case, increasing the variance in the distribution of ability at each college would reduce the variance in educational output, but it would also lower the average level of educational output.

APPENDIX A

Principal Components Analysis

In measuring the ability level of the students in this sample, we used scores on the principal components of a battery of 22 ability tests. In selecting the components to use in this analysis, we first estimated the relationship between the output measures and each of the 22 ability components. Only those components which had a substantial effect were used in the final analysis. The results of those preliminary analyses are described in Tables A-1 and A-2. It should be noted in the case of Table A-1 that, since the components are measured by raw scores, the signs and magnitude of the regression coefficients are difficult to interpret. Standardized regression coefficients provide a better guide to the magnitude of these effects.

In Table A-3, we have described the factor loadings of each of the initial test scores on each of the first four principal components. These loadings may provide some insight into the appropriate interpretation of these components.

TABLE A-1

Estimated Relationship between the Rate with Which Entrants Graduate College and the Student's Score on Each of Twenty-two Principal Components of Ability, Controlling for Various Other Inputs to the Educational Process

	Var.Mean	Reg.Coef.	T-stat.	Beta Coef.[b]
Principal component 1[a]	-107.931	- .4575	-3.37	.1047
" " 2[a]	- 16.567	-1.2118	-7.62	.1049
" " 3[a]	- 2.129	.7486	4.07	.0611
" " 4[a]	25.406	- .5448	-3.06	.0417
" " 5[a]	- 15.488	- .5205	-2.47	.0426
" " 6	- 13.805	.1980	.61	.0111
" " 7	- 16.031	- .4251	-2.22	.0281
" " 8	- .083	- .2375	.72	.0114
" " 9	- 26.275	- .2673	- .96	.0135
" " 10	28.268	.1064	.33	.0060
" " 11	13.284	- .1684	- .65	.0084
" " 12[a]	21.505	-1.0422	-3.66	.0531
" " 13	10.206	- .0438	- .15	.0018
" " 14	1.862	.4828	1.61	.0202
" " 15	- 47.023	.0477	.20	.0004
" " 16	10.283	.3310	1.08	.0160
" " 17	5.317	- .7617	2.32	.0270
" " 18	4.431	.0328	.12	.0016
" " 19	1.505	.5245	-1.55	.0235
" " 20	- 12.471	.1748	.52	.0079
" " 21	- 64.580	.1137	- .61	.0191
" " 22	- 4.268	1.0570	-3.18	.0327
Other input measures[c]				
Live at home/at school	.354	-6.99	-4.67	--
Work/not work	.504	17.65	8.28	--
Hours worked per week	11.490	-1.14	-15.23	--
Living expenses	656.48	.003	1.58	--
Research expenditures as a percent of total expend.	12.80	.070	1.15	--
Expenditure per pupil	22.47	.010	.66	--
Percent male	62.015	-.070	-1.69	--
Enrollment (thousands)	13.548	-.100	-1.97	--
Rate of graduation	66.7	--	--	--

[a]These principal components were used as measures of ability in subsequent analysis of the relationship between educational inputs and the rate of college graduation. The criterion for selecting these measures was primarily the size of the beta coefficient. At this preliminary stage of the analysis, the principal components were measured by raw scores rather than percentiles.

TABLE A-1 (cont'd.)

[b]This is the regression coefficient multiplied by the ratio of the standard deviation of the independent variable to the standard deviation of the dependent variable. This measure is useful in comparing the effect of various principal components since it converts their effect into comparable units.

[c]At the stage of the analysis in which all the principal components were included in the model, these variables constituted the other inputs examined. In subsequent analysis some of these measures were dropped and others were modified.

TABLE A-2

Estimated Relationship Between the Rate with which College Graduates Attend Graduate and Professional Schools and the Student's Score on Each of Twenty-two Principal Components of Ability, Controlling for Other Inputs to the Educational Process

	Var.Mean	Reg.Coef.	T-Stat.
Principal component 1[a]	23.628	-.4596	-3.09
" " 2[a]	32.565	-.2236	-3.58
" " 3[a]	30.571	.1318	2.45
" " 4[a]	53.733	-.0712	-1.37
" " 5	37.971	-.0329	- .52
" " 6	47.818	-.0640	- .99
" " 7	38.948	-.0184	- .38
" " 8	54.745	-.0513	- .90
" " 9	37.384	-.0179	- .30
" " 10[a]	69.850	-.2609	-3.14
" " 11	57.115	-.0354	- .69
" " 12	58.406	-.0535	- .96
" " 13	47.291	-.0185	- .39
" " 14	59.852	.0076	.16
" " 15	34.419	.0743	- .95
" " 16	64.028	.0034	.05
" " 17	61.188	.0200	.40
" " 18	61.080	.0055	.09
" " 19	43.534	.0276	.48
" " 20	43.980	.1537	-2.58
" " 21	28.517	.0273	.20
" " 22	43.561	.0752	1.37
Other input measures			
Living expenditure	655.88	.002	.59
Work/not work	.472	6.60	1.89
Hours worked	9.210	-.578	-4.00
Expend. on faculty	590.93	.003	1.17
Average ability	68.32	.092	.784
Enrollment	16.58	.761	3.03
$Enrollment^2$	438.97	-.011	-2.42
Rate of graduate school attendance			

[a]These variables were included as measures of ability in subsequent analyses of the relationship between educational inputs and the rate with which graduates attend graduate and professional schools. The criterion used for selection was the magnitude of the regressive coefficients. At this stage of the analysis the principal component scores were measured in percentile terms.

TABLE A-3

Coefficients (Factor Loadings) Relating the First Four Principal Components of Ability to Each of Twenty-Two Ability Tests

Test title	After rotation to maximize variation in these weights (1)	(2)	(3)	(4)
(1) General information	.823	.243	.299	.111
(2) Knowledge of literature	.804	.079	.319	.090
(3) Knowledge of music	.763	.094	.221	.046
(4) Knowledge of vocabulary	.756	.235	.368	.081
(5) Knowledge of social studies	.748	.115	.362	.042
(6) Reading comprehension	.717	.317	.317	.179
(7) Disguised words	.611	.274	.108	.224
(8) Knowledge of physical science	.590	.277	.532	.034
(9) Scientific attitude	.557	.214	.271	.063
(10) Creativity	.545	.508	.145	.182
(11) Knowledge of English usage	.502	.162	.490	.337
(12) Visualization in three dimensions	.150	.780	.246	.021
(13) Mechanical reasoning	.276	.764	.230	.062
(14) Visualization in two dimensions	.091	.747	.073	.078
(15) Abstract reasoning	.284	.601	.365	.106
(16) Mathematics test I	.338	.240	.822	.133
(17) Mathematics test II	.259	.193	.817	.081
(18) Knowledge of mathematics	.455	.223	.763	.072
(19) Arithmetic reasoning	.380	.310	.624	.176
(20) Word functions in sentences	.389	.249	.560	.225
(21) Memory for sentences	.022	.100	.042	.853
(22) Memory for words	.286	.066	.289	.633

APPENDIX B

Logit Analysis

An alternative approach which avoids some of the statistical and conceptual difficulties posed by the linear model is logit analysis. This model assumes a linear relationship between the inputs to the educational process and the log odds of graduation and graduate school attendance. In order to compare the results of this form of analysis with those derived from the linear model, we have estimated the log odds of graduation and graduate school attendance for each of the colleges in this sample and used multiple regression analysis to estimate the relation between these measures and each of the inputs to the educational process. Since the data is now grouped by college, a limited set of input measures is examined. In particular, we no longer could distinguish between individual and average ability levels, and the coefficient on the ability measures for the students in each college reflects the combination of these influences. We have also omitted the measures of student environment--living at home, working for pay, and living expenditures--since aggregating across the students in each college would alter the meaning of these variables. Since these alterations affect the parameters of the model, we also estimated the parameters of the linear additive model using this limited subset of inputs. The estimated parameters of the logit model are described in Table B-1 and those for the linear model in Table B-2. In both cases, the data were weighted to adjust for the heteroscedasticity which results from grouping.

In order to compare the results of these two models, we have estimated from the logit model the effect of a unit change in each of the input measures on the rates of graduation and graduate school attendance. These

TABLE B-1

Regression Coefficients Relating Measures of Educational Input[a] to the Log Odds of Entrants Graduating and Graduates Attending Graduate and Professional Schools. Estimates Based on Data Grouped by College Attended

	Log odds of graduation					Log odds of graduate or professional school				
	Mean	Reg. Coef.	Stand. Error	Sig.[b] Level	$\frac{\Delta\% \text{ grad.}^c}{\Delta X_i}$	Mean	Reg. Coef.	Stand. Error	Sig.[b] Level	$\frac{\Delta\% \text{ att.}^c}{\Delta X_i}$
Constant	1.0	-4.14	.662	.000+	--	1.0	-2.60	.875	.003	--
Ability measure 1	70.4	.029	.008	.000+	.725	70.4	.010	.011	.352	.250
Ability measure 2	62.0	.025	.007	.000+	.625	62.0	.014	.009	.100	.350
Ability measure 3	51.1	.013	.006	.031	.325	51.1	- .019	.008	.019	-.475
Ability measure 4	49.2	.006	.007	.368	.150	49.2	.002	.009	.817	.050
Ability measure 5	56.1	.011	.008	.138	.275	56.1	.013	.010	.180	.325
Student-faculty ratio	21.3	-.029	.008	.000+	-.725	21.3	.029	.010	.007	.725
Expend. per student on instruc. rel. act.	12.81	.0001	.016	.999+	.003	12.81	.039	.022	.080	.975
Expend. per student on org. research & ext.	7.03	.005	.008	.502	.125	7.03	.004	.011	.726	.100
Enrollment	11.9	-.029	.017	.091	-.725	11.9	-.002	.022	.936	-.050
Enrollment^2	234.1	.0004	.0004	.238	.010	234.1	-.0001	.0005	.872	-.002
Log odds of grad.	.296									
Log odds of grad. school attend.						.046				
R^2		.569				.283				
N		169				169				

[a]See Table 20, note a.

[b]See Table 1, note b.

[c]Estimated at the mean for each of the input measures.

Since: $\ln\frac{P(x)}{1-P(x)} = a + bx$

$$\frac{dP(x)}{dx} = b\,(P(x) - P(x)^2)$$

where: P(x) = the probability of graduation (graduate school attendance) for entrants (graduates), with input characteristics described by the vector x. Resultant derivatives have been scaled by 100 to reflect change in percent graduating or attending graduate school.

TABLE B-2

Regression Coefficients Relating Measures of Educational Input[a] to the Rate with which Entrants Graduate and Graduates Attend Graduate and Professional Schools, Estimates Based on Data Grouped by College Attended

	Rate of graduation				Rate of graduate school attendance			
	Mean	Reg. Coef.	Stand. Error	Sig.[b] Level	Mean	Reg. Coef.	Stand. Error	Sig.[b] Level
Constant	1.0	-34.7	12.6	.006	1.0	-9.96	15.6	.528
Ability measure 1	70.4	.673	.164	.000+	70.4	.116	.203	.569
Ability measure 2	62.0	.499	.126	.000+	62.0	.311	.157	.048
Ability measure 3	51.1	.245	.118	.038	51.1	-.367	.147	.012
Ability measure 4	49.2	.163	.129	.207	49.2	.080	.160	.617
Ability measure 5	56.1	.158	.144	.271	56.1	.413	.179	.020
Student-faculty ratio	21.3	-.566	.157	.000+	21.3	.525	.194	.007
Expend. per student on instruct. rel. act.	12.81	-.294	.323	.362	12.81	.908	.401	.023
Expend. per student on org. research and extension	7.03	.169	.166	.307	7.03	.000+	.002	.865
Enrollment	11.9	-.382	.330	.246	11.9	.140	.409	.733
$Enrollment^2$	234.1	.006	.008	.435	234.1	-.005	.009	.631
% of entrants grad.	55.4							
% of grad. attending grad. & professional schools					49.6			
R^2		.779				.634		
N		169				169		

[a]The regression coefficients reflect the change in the rate of graduation for a unit change in each of these input measures. The ability variables are measured in percentiles, living expenditures, research expenditures, and instructional expenditures are measured in hundreds of dollars and enrollment is measured in thousands of students.

[b]See Table 1, note b.

estimates were made holding each of the other input measures constant at their mean levels. These estimates are generally less than one standard deviation away from the estimate derived from the linear model. Moreover, since at the mean value of each of these inputs the estimated probabilities of graduation and graduate school attendance are about .5, the effects of each input estimated from the logit model reflects the maximum effect of that variable. Since these estimates are generally above those derived from the linear model, choosing other input values would produce estimates closer to those derived from the linear model. While the estimates of R^2 for each of these models suggest that the linear model fits the data better than the logit model, no rigorous comparison of fit has been made.

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