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Graduation, Graduate School Attendance, and Investments in College Training

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, an output which 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. When 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, I 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—referred to as educational production functions—and using multiple regression analysis to estimate the parameters of these functions. These parameters are estimated from data describing the input and outputs of the college experience for a large sample of students entering college in 1960.

There are three primary objectives of this effort that attempts 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, the results of a number of other studies of the relationships between specific inputs and outputs of the college process are examined. 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 among 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. Moreover, 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.

Weisbrod and Karpoff [26] examine the relationship among the earnings of college graduates, their ability, and the quality of the college they attended. In their 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 investment.

The most recent examination of this relationship is that of Daniere and Mechling [11]. In this study they construct 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 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 the 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], Thistlethwaite [25], and Astin [1] all try to remedy this deficiency, and their studies suggest a more modest rôle 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 socioeconomic 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, and 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

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III. THE MODE

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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.

III. THE MODEL

Data Sources

In analyzing the production of educational services, data on students from the Project Talent data bank were used.[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 measures 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 the ability to generalize from the results of this study. If no significant relationship between these measures and the inputs to the educational process is found, 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 indexes 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. The graduate or professional school, in

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admitting this student, is expressing satisfaction with the caliber 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

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

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; and
- ϵ_i = a stochastic term.

Multiple regression analysis is used 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

$$VAR(\epsilon_i) = (X'_i\beta) - X'_i\beta) \qquad (2)$$

where

- X_i = the vector of input values for the ith student; and
- β = the vector of parameters;

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

$$\gamma_i Y_i = \gamma_i X'_i\beta + \gamma_i\epsilon_i \qquad (3)$$

where

$$\gamma_i = \frac{1}{X'_i\beta(1 - X'_i\beta)}. \qquad (4)$$

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, an estimate of the parameters of these equations using ordinary least squares was first obtained. These 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 these 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, this problem is dealt with 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, the possibility that the productivity of that variable depends upon its level is considered. To explore the possibility of other forms of nonlinearity, the students are divided 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, the extent and magnitude of interaction among the inputs to the educational process is examined.

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]

At the time the student decides whether or not to attend graduate school, these skills have been altered by the nature of the undergraduate

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
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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	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Ability measure 1 (percentiles)	72.06	21.11	70.77	21.48	75.73	19.60
Ability measure 2 (percentiles)	63.65	24.29	62.01	24.66	68.33	22.60
Ability measure 3 (percentiles)	49.32	26.95	49.15	26.96	49.79	26.93
Ability measure 4 (percentiles)	47.22	27.11	47.44	27.05	46.58	27.30
Ability measure 5 (percentiles)	58.76	28.02	57.39	28.11	62.66	27.39
Ability measure 12 (percentiles)	43.47	25.73	43.64	25.39	42.97	26.66
Average ability (percentiles)	72.21	10.70	70.70	9.91	76.47	11.65
Living expenses (hundreds of dollars)	6.23	4.24	6.02	3.87	6.81	5.09
Working for pay[a]	.506	.500	.504	.500	.513	.500
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
Expenditure per student on instruction-related activities (hundreds of dollars)	13.25	5.29	12.52	4.49	15.33	6.65
Expenditure per student on organized research and extension (hundreds of 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 (thousands)	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 means and standard deviations 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	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Ability measure 1 (percentiles)	76.19	18.51	74.85	18.65	79.32	17.86
Ability measure 2 (percentiles)	67.41	22.57	65.53	23.16	71.93	20.46
Ability measure 3 (percentiles)	50.38	26.62	50.19	26.67	51.05	26.44
Ability measure 4 (percentiles)	46.31	26.74	47.05	26.66	44.57	26.83
Ability measure 10 (percentiles)	30.63	20.76	30.96	20.28	29.82	21.47
Average ability (percentiles)	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
Expenditure per student on instruction-related activities (hundreds of dollars)	13.93	5.62	12.89	4.55	16.36	6.97
Expenditure per student on organized research and extension (hundreds of dollars)	9.30	10.48	8.82	9.44	10.42	12.52
Enrollment (thousands)	15.6	10.6	18.4	10.8	8.8	6.2
Enrollment^2 (thousands)	354.6	438.4	455.6	480.1	118.9	151.2
College major						
Math & physical sciences [a]	.254	.436	.261	.439	.239	.427
Social sciences & humanities [a]	.315	.465	.306	.461	.337	.473
Prelaw, premedicine, predentistry [a]	.013	.111	.012	.110	.014	.116

Working for pay[a]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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
Expenditure per student on instruction-related activities (hundreds of dollars)	13.93	5.62	12.89	4.55	16.36	6.97
Expenditure per student on organized research and extension (hundreds of dollars)	9.30	10.48	8.82	9.44	10.42	12.52
Enrollment (thousands)	15.6	10.6	18.4	10.8	8.8	6.2
Enrollment² (thousands)	354.6	438.4	455.6	480.1	118.9	151.2
College major						
Math & physical sciences[a]	.254	.436	.261	.439	.239	.427
Social sciences & humanities[a]	.315	.465	.306	.461	.337	.473
Prelaw, premedicine, predentistry[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*.

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 depends 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, a dummy variable which takes on the value one if the student works and is zero otherwise is also included.

In addition, the students in the sample varied in the nature of their living environments while in college. About 40 per cent of the students in the 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 live at school. To reflect this possibility, the model includes 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 that they spend on their living accommodations while in college. While the average student in the sample reported spending about $600 per year on room, board, and other college expenses, 13.2 per cent spent $1,000 or more per year, and 33 per cent 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 or 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

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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 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 are 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, the effects of other components of expenditures would be obscured 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 deleterious to the educational process. In order to measure these economies and diseconomies of scale, both enrollment and the square of enrollment are included as inputs to the educational process.

The quality of a college may depend not only on the quality of its facilities but on the quality of the student body. Students clearly learn from each other as well as from 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, a measure of the average ability level of the students at each of the colleges in this sample has been included. This measure is 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, an effort has been made to hold constant 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, and so forth). 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.

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

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		
Regression Coefficient	Standard Error	Significance Level[b]	Regression Coefficient	Standard Error	Significance Level[b]	Regression Coefficient	Standard Error	Significance Level[b]

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		
	Regression Coefficient	Standard Error	Significance Level[b]	Regression Coefficient	Standard Error	Significance Level[b]	Regression Coefficient	Standard Error	Significance Level[b]
Constant	−11.08	7.49	.141	−15.44	9.04	.087	7.62	18.49	.681
Ability measure 1 (percentiles)	.449	.045	.000+	.442	.052	.000+	.448	.097	.000+
Ability measure 2 (percentiles)	.307	.036	.000+	.294	.042	.000+	.336	.070	.000+
Ability measure 3 (percentiles)	.105	.030	.000+	.127	.036	.000+	.065	.051	.204
Ability measure 4 (percentiles)	.079	.032	.013	.115	.039	.003	.004	.057	.944
Ability measure 5 (percentiles)	.103	.034	.002	.130	.041	.002	.015	.063	.810
Ability measure 12 (percentiles)	.121	.033	.000+	.092	.041	.025	.147	.058	.012
Average ability (percentiles)	.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
Expenditure per student on instruction-related activities	−.200	.210	.332	−.630	.290	.031	−.610	.480	.200

TABLE 3 (concluded)

	All Schools			Public Schools			Private Schools		
	Regression Coefficient	Standard Error	Significance Level[b]	Regression Coefficient	Standard Error	Significance Level[b]	Regression Coefficient	Standard Error	Significance Level[b]
Expenditure per student on organized research and extension	.220	.100	.030	.230	.120	.066	.320	.230	.167
Enrollment	.028	.244	.912	−.150	.361	.674	3.57	.916	.000+
Enrollment²	−.003	.006	.667	.003	.008	.704	−.140	.038	.000+
R^2	.468			.325			.667		
F	159.50			64.73			91.48		
Number	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 per cent 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		
	Regression Coefficient	Standard Error	Significance Level[b]	Regression Coefficient	Standard Error	Significance Level[b]	Regression Coefficient	Standard Error	Significance Level[b]

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		
	Regression Coefficient	Standard Error	Significance Level[b]	Regression Coefficient	Standard Error	Significance Level[b]	Regression Coefficient	Standard Error	Significance Level[b]
Constant	−.70.12	10.09	.000+	−87.49	11.26	.000+	−13.58	28.29	.631
Ability measure 1 (percentiles)	.116	.078	.139	.076	.087	.384	.209	.166	.207
Ability measure 2 (percentiles)	.165	.045	.000+	.185	.052	.000+	.178	.092	.052
Ability measure 3 (percentiles)	.046	.035	.187	−.048	.040	.234	.263	.066	.000+
Ability measure 4 (percentiles)	−.017	.037	.660	.057	.044	.186	−.127	.071	.073
Ability measure 10 (percentiles)	.083	.059	.152	.181	.068	.008	−.091	.113	.424
Average ability (percentiles)	.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
Expenditure per student on instruction-related activities	1.150	.270	.000+	1.740	.360	.000+	.040	.670	.960
Expenditure per student on organized research & extension	−.010	.140	.920	.040	.160	.794	.340	.310	.267

TABLE 4 (concluded)

	All Schools			Public Schools			Private Schools		
	Regression Coefficient	Standard Error	Significance Level[b]	Regression Coefficient	Standard Error	Significance Level[b]	Regression Coefficient	Standard Error	Significance Level[b]
Enrollment	.949	.319	.003	.827	.476	.084	3.16	1.14	.006
Enrollment²	−.022	.008	.005	−.022	.010	.032	−.128	.047	.007
College major									
Math & physical sciences	12.61	2.36	.000+	9.77	2.74	.000+	14.31	4.45	.001
Social sciences & humanities	5.45	2.22	.014	5.26	2.59	.042	.116	4.19	.984
Prelaw, premedicine, predentistry	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		
Number	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 per cent 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*.
[c] See Table 3, note c.

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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, 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 college. As a result of this difference, if those not attending were to attend college, they would have a graduation rate 25 percentage 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 affect adversely 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 while in college is less straightforward. Living expenditure, which is not

TABLE 5 Regression Coefficients Relating Grades in College[a] to Measures of Input to the Educational Process

	Variable Mean	Regression Coefficient	Standard Error	Significance Level[b]
Constant	1.0	5.47	.574	.000+
Ability measure 1 (percentiles)	76.3	.025	.002	.000+
Ability measure 2 (percentiles)	67.4	.005	.002	.009
Ability measure 3 (percentiles)	50.6	.007	.001	.000+
Ability measure 4 (percentiles)	53.7	.000+	.002	.865
Ability measure 5 (percentiles)	62.0	−.003	.002	.037
Average ability 1 (percentiles)	73.2	−.006	.006	.337
Average ability 2 (percentiles)	63.5	−.009	.004	.042
Average ability 3 (percentiles)	51.8	−.002	.005	.631
Average ability 4 (percentiles)	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			
Number	2,245			

[a] Grades are measured on a twelve-point scale from D− to A+.
[b] See Table 3, note *b*.

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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 on both graduation 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 does not live 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 live 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 has 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. The 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 is suggested at the outset, degree standards 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, the parameters of the college production function for public and private colleges have been estimated 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. This 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 private 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 the ratio is high. Since public and private colleges differ widely with respect to the student-faculty ratio, enrollment, and the per cent 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 colleges 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, the parameters of this model have been estimated separately for

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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 was low may also be described as high input in other respects as well. The students in these colleges scored higher on ability tests and were less likely to work for pay while in college than those attending colleges where the student-faculty ratio was high. These colleges also spent 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 *increase* the graduation rate by .4 percentage points. In schools where the student-faculty ratio was below 20:1, each unit reduction appears to *reduce* 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 appear to be complements of the student-faculty ratio.[12] The adverse effects of working for pay while in college begin after fewer hours of work and more severely 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, the parameters of the model relating these inputs

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	Regression Coefficient	Standard Error	Significance Level[b]	Mean	Regression Coefficient	Standard Error	Significance Level[b]
Constant	1.0	−48.7	14.8	.000+	1.0	−16.0	10.6	.131
Ability measure 1 (percentiles)	75.4	.482	.073	.000+	69.5	.397	.061	.000+
Ability measure 2 (percentiles)	63.8	.249	.056	.000+	63.6	.312	.048	.000+
Ability measure 3 (percentiles)	50.5	.161	.045	.000+	48.4	.111	.043	.010
Ability measure 4 (percentiles)	47.1	.133	.049	.007	47.3	.114	.046	.014
Ability measure 5 (percentiles)	60.0	.118	.053	.025	57.8	.129	.049	.009
Ability measure 12 (percentiles)	42.1	.076	.052	.144	44.5	.125	.047	.009
Average ability (percentiles)	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	.135	.000+	13.5	−1.11	.119	.000+
Student-faculty ratio	14.5	1.02	.394	.010	26.0	−.412	.204	.044
Expenditure per student on instruction-related activities	15.25	−.300	.270	.257	11.76	.070	.530	.897
Expenditure 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
Enrollment²	258.3	.028	.015	.057	408.8	.002	.008	.841
R^2	.216				.163			
F	24.54				23.30			
Number	1,351				1,804			

[a] An F statistic testing the hypothesis that the slope coefficients of these two regressions are the same is 1.88 with 15 and 3,125 degrees of freedom. This is significant at the 5 per cent 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			
Variable Mean	Regression Coefficient	Standard Error	Significance Level[b]	Variable Mean	Regression Coefficient	Standard Error	Significance Level[b]

Enrollment	[illegible]	[illegible]
R^2	.216	.163
F	24.54	23.30
Number	1,351	1,804

[a] An F statistic testing the hypothesis that the slope coefficients of these two regressions are the same is 1.88 with 15 and 3,125 degrees of freedom. This is significant at the 5 per cent 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			
	Variable Mean	Regression Coefficient	Standard Error	Significance Level[b]	Variable Mean	Regression Coefficient	Standard Error	Significance Level[b]
Constant	1.0	−88.3	18.6	.000+	1.0	−86.5	15.8	.000+
Ability measure 1 (percentiles)	80.7	.021	.115	.857	71.1	.099	.106	.352
Ability measure 2 (percentiles)	70.5	.193	.067	.004	64.0	.176	.064	.006
Ability measure 3 (percentiles)	50.4	.046	.050	.362	50.4	−.019	.052	.711
Ability measure 4 (percentiles)	45.8	.082	.054	.129	46.8	−.016	.055	.771
Ability measure 10 (percentiles)	28.0	.055	.085	.515	33.6	.093	.083	.256
Average ability (percentiles)	79.4	.414	.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
Expenditure per student on instruction-related activities	17.81	1.021	.400	.010	9.55	2.16	1.080	.044
Expenditure 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
Enrollment²	488.0	−.018	.010	.082	203.9	−.032	.015	.033
College major								
Math & physical sciences	.274	10.2	3.29	.002	.232	13.9	3.59	.000+
Social sciences & humanities	.304	5.48	3.14	.082	.328	1.89	3.25	.562
Prelaw, premedicine, predentistry	.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			
Number	1,306				1,158			

[a] An F statistic testing the hypothesis that the slope coefficient of these two regressions are the same is 2.10 with 20 and 2,424 degrees of freedom. This is significant at the 1 per cent 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			
	Variable Mean	Regression Coefficient	Standard Error	Significance Level[b]	Variable Mean	Regression Coefficient	Standard Error	Significance Level[b]
Constant	1.0	−83.4	21.1	.000+	1.0	−74.0	13.5	.000+
Ability measure 1 (percentiles)	80.5	−.038	.131	.772	73.3	.104	.097	.280
Ability measure 2 (percentiles)	69.0	.178	.076	.019	66.3	.194	.059	.000+
Ability measure 3 (percentiles)	52.8	.066	.058	.256	48.8	−.017	.047	.711
Ability measure 4 (percentiles)	46.1	.054	.063	.395	46.4	.011	.049	.818
Ability measure 10 (percentiles)	26.3	.019	.099	.841	33.5	.091	.075	.222
Average ability (percentiles)	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
Expenditure per student on instruction-related activities	18.05	1.110	.410	.006	11.18	1.372	.490	.005
Expenditure 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
Enrollment²	459.4	−.001	.012	.912	284.6	−.023	.012	.061
College major:								
Math & physical sciences	.294	8.51	3.61	.019	.228	14.69	3.26	.000+
Social sciences & humanities	.274	9.52	3.71	.010	.343	.374	2.86	.897
Prelaw, premedicine, predentistry	.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			
Number	986				1,478			

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

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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 & physical sciences	.294	8.51	3.61	.019	.228	14.69	3.26	.000+
Social sciences & humanities	.274	9.52	3.71	.010	.343	.374	2.86	.897
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[a] An F statistic-testing the hypothesis that the slope coefficients of these two regressions is the same was 2.04 with 20 and 2,424 degrees of freedom. This is significant at the 1 per cent level.

[b] See Table

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

Second, 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 diminishes as the level 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.

Third, 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, a similar difference is found 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. 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 precollege 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 ninetieth 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 thirtieth 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 guidelines 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. The model suggests that by increasing instructional expenditures, 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 that improving the quality of the capital market for students investing in education might improve the educational opportunities of low-income students. To the extent that 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 with 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.

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Logit Analysis

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APPENDIX A

Principal Components Analysis

In measuring the ability level of the students in this sample, scores on the principal components of a battery of 22 ability tests were used. In selecting the components to use in this analysis, the relationship between the output measures and each of the 22 ability components was estimated. 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, the factor loadings of each of the initial test scores on each of the first four principal components are described. These loadings may provide some insight into the appropriate interpretation of these components.

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, the log odds of graduation and graduate school attendance have been estimated for each of the colleges in this sample. Multiple regression analysis was used to estimate the relation between these measures and each of the inputs to the educational process. Since the data are now grouped by college, a limited set of input measures is examined. In particular, it was no longer possible to 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. Measures of student environment—living at home, working for pay, and living expenditures have also been omitted—since aggregating across the students in each

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

	Variable Mean	Regression Coefficient	*t*-Statistic	Beta Coefficient[b]
Principal component 1[a]	−107.931	−.4575	−3.37	.1047
Principal component 2[a]	−16.567	−1.2118	−7.62	.1049
Principal component 3[a]	−2.129	.7486	4.07	.0611
Principal component 4[a]	25.406	−.5448	−3.06	.0417
Principal component 5[a]	−15.488	−.5205	−2.47	.0426
Principal component 6	−13.805	.1980	.61	.0111
Principal component 7	−16.031	−.4251	−2.22	.0281
Principal component 8	−.083	−.2375	.72	.0114
Principal component 9	−26.275	−.2673	−.96	.0135
Principal component 10	28.268	.1064	.33	.0060
Principal component 11	13.284	−.1684	−.65	.0084
Principal component 12[a]	21.505	−1.0422	−3.66	.0531
Principal component 13	10.206	−.0438	−.15	.0018
Principal component 14	1.862	.4828	1.61	.0202
Principal component 15	−47.023	.0477	.20	.0004
Principal component 16	10.283	.3310	1.08	.0160
Principal component 17	5.317	−.7617	2.32	.0270
Principal component 18	4.431	.0328	.12	.0016
Principal component 19	1.505	.5245	−1.55	.0235
Principal component 20	−12.471	.1748	.52	.0079
Principal component 21	−64.580	.1137	−.61	.0191
Principal component 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 expenditure as a per cent of total expenditure	12.80	.070	1.15	–
Expenditure per pupil	22.47	.010	.66	–
Per cent 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.

[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

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[a] These variables were between educational schools. The criterion of the analysis the pr

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

	Variable Mean	Regression Coefficient	t-Statistic
Principal component 1[a]	23.628	−.4596	−3.09
Principal component 2[a]	32.565	−.2236	−3.58
Principal component 3[a]	30.571	.1318	2.45
Principal component 4[a]	53.733	−.0712	−1.37
Principal component 5	37.971	−.0329	−.52
Principal component 6	47.818	−.0640	−.99
Principal component 7	38.948	−.0184	−.38
Principal component 8	54.745	−.0513	−.90
Principal component 9	37.384	−.0179	−.30
Principal component 10[a]	69.850	−.2609	−3.14
Principal component 11	57.115	−.0354	−.69
Principal component 12	58.406	−.0535	−.96
Principal component 13	47.291	−.0185	−.39
Principal component 14	59.852	.0076	.16
Principal component 15	34.419	.0743	−.95
Principal component 16	64.028	.0034	.05
Principal component 17	61.188	.0200	.40
Principal component 18	61.080	.0055	.09
Principal component 19	43.534	.0276	.48
Principal component 20	43.980	.1537	−2.58
Principal component 21	28.517	.0273	.20
Principal component 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
Expenditure on faculty	590.93	.003	1.17
Average ability	68.32	.092	.784
Enrollment	16.58	.761	3.03
Enrollment²	438.97	−.011	−2.42

[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

college would alter the meaning of these variables. Since these alterations affect the parameters of the model, the parameters of the linear additive model are also estimated 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, the effect of a unit change in each of the input measures on the rates of graduation and graduate school attendance has been estimated from the logit model. These 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

TABLE B-1 Regression Coefficients Relating Measures of Educational Input 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 School Attendance

TABLE B-1 Regression Coefficients Relating Measures of Educational Input 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 School Attendance				
	Mean	Regression Coefficient	Standard Error	Significance Level[a]	Δ% Graduation[b] / ΔX_1	Mean	Regression Coefficient	Standard Error	Significance Level[a]	Δ%Attendance[b] / ΔX_1
Constant	1.0	−4.14	.662	.000+	–	1.0	−2.60	.875	.003	–
Ability measure 1 (percentiles)	70.4	.029	.008	.000+	.725	70.4	.010	.011	.352	.250
Ability measure 2 (percentiles)	62.0	.025	.007	.000+	.625	62.0	.014	.009	.100	.350
Ability measure 3 (percentiles)	51.1	.013	.006	.031	.325	51.1	−.019	.008	.019	−.475
Ability measure 4 (percentiles)	49.2	.006	.007	.368	.150	49.2	.002	.009	.817	.050
Ability measure 5 (percentiles)	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
Expenditure per student on instruction-related activity	12.81	.0001	.016	.999+	.003	12.81	.039	.022	.080	.975
Expenditure per student on organized research and extension	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
Enrollment²	234.1	.0004	.0004	.238	.010	234.1	−.0001	.0005	.872	−.002
Log odds of graduation	.296									
Log odds of graduate school attendance						.046				
R^2		.569				.283				
Number		169				169				

[a] See Table 3, note *b*.
[b] Estimated at the mean for each of the input measures.

Since: $\ln P(x)/1 - P(x) = a + bx$

$dP(x)/dx = b\,[P(x) - P(x)^2]$

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 *per cent* graduating or attending graduate school.

TABLE B-2 Regression Coefficients Relating Measures of Educational Input 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	Regression Coefficient	Standard Error	Significance Level[a]	Mean	Regression Coefficient	Standard Error	Significance Level[a]
Constant	1.0	−34.7	12.6	.006	1.0	−9.96	15.6	.528
Ability measure 1 (percentiles)	70.4	.673	.164	.000+	70.4	.116	.203	.569
Ability measure 2 (percentiles)	62.0	.499	.126	.000+	62.0	.311	.157	.048
Ability measure 3 (percentiles)	51.1	.245	.118	.038	51.1	−.367	.147	.012
Ability measure 4 (percentiles)	49.2	.163	.129	.207	49.2	.080	.160	.617
Ability measure 5 (percentiles)	56.1	.158	.144	.271	56.1	.413	.179	.020
Student-faculty ratio	21.3	−.566	.157	.000+	21.3	.525	.194	.007
Expenditure per student on instruction-related activity	12.81	−.294	.323	.362	12.81	.908	.401	.023
Expenditure per student on *organized* research and extension	7.03	.169	.166	.307	7.03	.000+	.002	.865
Enrollment	11.9	−.382	.330	.246	11.9	.140	.409	.733
Enrollment²	234.1	.006	.008	.435	234.1	−.005	.009	.631
Per cent of entrants graduating	55.4							
Per cent of graduates attending graduate and professional schools					49.6			
R^2		.779				.634		
Number		169				169		

Note: 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. Instructional expenditures are measured in hundreds of dollars and enrollment is measured in thousands of students.

[a] See Table 1, note *b*.

Note: 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. Instructional expenditures are measured in hundreds of dollars and enrollment is measured in thousands of students.

[a] See Table 1, note *b*.

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.

NOTES

1. This view underlies the work in this 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* 75 (August 1967): 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, D.C.: Government Printing Office, 1966); and Alexander W. Astin, "Undergraduate Achievement and Institutional Excellence," *Science* 161 (August 16, 1968): 611–617.
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," *Journal of Human Resources* 3 (Winter 1968): 3–24; Glen C. Cain and Harold W. Watts, "Problems in Making Policy Inferences from the Coleman Report," *American Sociology Review* 35 (April 1970): 228–241; Samuel Bowles and Henry M. Levin, "More on Multicollinearity and the Effectiveness of the Schools," *Journal of Human Resources* 3 (Summer 1968): 393–400.
4. The Project Talent data bank is a cooperative effort of the U.S. Office of Education, the University of Pittsburgh, and the American Institute 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. These data have 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, I would like to point out that the design and interpretation of the research reported herein are solely my own responsibility.
5. The Higher Education General Information Survey is an ongoing 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, I used data on finances, enrollment, and employees from the 1966 HEGIS.
6. For a discussion of this method, see J. Johnston, *Econometric Methods* (New York:

McGraw-Hill, 1962), pp. 227–228. An alternative approach to the problem of heteroscedasticity, logit analysis, is explained in Appendix B.

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* (New York: McGraw-Hill, 1967), pp. 221–258.
8. The results of these preliminary analyses are described in Appendix A.
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.
10. This estimate was computed as follows

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

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 expenditures 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; and
TE = total expenditures at the ith college.

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 were gathered from a stratified, random sample of schools and a cluster sample of students, the actual variance of sample means might be a little larger or smaller than that estimated from these data. However, since 80 per cent 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.
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.

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3 COMMENTS

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Educational Testing Service

There are many good reasons besides the current financial crisis for acquiring a comprehensive knowledge of the effects of higher education. Without such knowledge, we cannot organize new colleges or reorganize old ones to exert more effective influence. The present practice of making decisions by rule of thumb or through political pressure tends to support the status quo or to encourage the following of fads. Moreover, this knowledge is needed to make the training of our limited supplies of talented people, as well as the use of supporting resources, more productive.

However, such knowledge requires a long-term effort and a recognition of the many complexities involved in assessing the effects of college. I should now like to outline some of the basic elements needed to carry out such assessments, endeavoring to relate these elements to Perl's study. There are six such elements. First, we need to know what colleges are trying to accomplish, that is, their goals. Second, we need to know what students are like when they enter college, because their final status is usually highly dependent on their initial status. Third, and related to the first two elements, we need to know the criteria that represent an adequate approximation of a college's aims for its students. Fourth, we need to know how to describe the characteristics of the college environment both empirically and in terms of theory. Fifth, we need to know the technical or statistical models that are most appropriate for assessing effects. And sixth, we need to know who is going to use this information and for what purposes.

Clearly, these elements cannot be presented adequately in fifteen minutes. Books and monographs (e.g., Feldman and Newcomb, 1969; Astin, 1970) have been written about these issues. But I should like to analyze the elements as they apply to the paper under discussion.

First, the goals of higher education have been the subject of a great deal of rhetoric and a very small amount of research (Peterson, 1970). However, it is clear that most institutions would consider their goals to include a good deal more than the processing of students to maximize their standing according to some objective economic measure. Of course, no single study can study every goal, but it should be remembered that institutions often emphasize a variety of goals, such as contributing to knowledge, providing leadership for various organizations, meeting local needs, general public service, vocational preparation, social activism, students' intellectual development, and students' personal development. Some of these goals have economic implications, some do not. Any study should be seen in the general context of the variety of institutional goals and functions, and, before

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its results are taken as guides for action, it should be examined in terms of the variety of goals that it does not consider, as well as those that it does.

The second element, adequately assessing student input in order to assess students' progress, also requires a recognition of variety. Various studies have shown that entering classes differ widely with respect to such variables as academic potentials, educational and vocational aspirations, life goals, potentials for original accomplishment, personality traits, values, parental attitudes, and socioeconomic status. (Again, see Feldman and Newcomb, 1969.) In particular, a variety of these characteristics have been related to college graduation and to postgraduate education (e.g., Astin and Panos, 1969; Snyder, 1969). Even more particularly, Project Talent data have been used to relate cognitive *and* noncognitive variables to college graduation (Bayer, 1968; Schoenfeldt, Bayer, and Brown, 1970). I wonder why this study did not use the Project Talent measures of interests, personality, and socioeconomic status, since they were presumably available. The last variable mentioned especially merits inclusion. Other basic characteristics, such as sex and ethnic group, could also have been used for breakdowns of the analyses. The study would have been much stronger if these features had been included. As it now stands, there are a number of unanswered questions.

A variety of inputs is also important to an assessment of the factors involved in meeting the requirements of the third element, defining criteria of student outcomes. Again, the chief purpose of mentioning this element is to help place the study in context. While it is difficult to place some criteria in operational terms, a number of them can be operationalized: actual subject-matter knowledge (Rock, Baird, and Linn, 1971); values (see Feldman and Newcomb); career plans and aspirations (Davis, 1965); and such variables as participation in organizations (Pace, 1969) or changes on personality scales (Chickering, 1969). This diversity of criteria of student outcomes is especially critical in drawing policy conclusions from college impact research. Caution is especially advisable because the college characteristics that seem to be positively related to one of these criteria may be negatively related to others. For example, a recent study (Rock, Baird, and Linn), found that even within the relatively well defined area of academic knowledge, different environmental characteristics were related to achievement in the humanities versus the social sciences. Furthermore, not one college was in both the group of colleges most effective in fostering knowledge of humanities and the group most effective in fostering knowledge of social science. To revert to the criteria used in the study we are discussing, it would have been a better study if it had differentiated between students who dropped out voluntarily, and those who flunked out, and between those who entered relatively high-quality graduate programs and those entering lower-quality programs. For the purposes of manpower distribution, these distinctions may make little difference, but for students choosing various educational careers, they may be critical.

The fourth element, describing the characteristics of the institutional environment is a most vexing one, as evidenced by the great variety of approaches used (Astin, 1965, 1968; Pace, 1968; Feldman, 1971). In general, however, it is useful to distinguish between: (1) measures based on the aggregate characteristics of the people *in* the environment (e.g., Holland and Astin, 1961; Richards et al., 1970), and those based on the characteristics of the environment as distinct from the people in it (Baird, 1971); (2) measures of *between* college environmental variables (e.g., Pace, 1968) and *within* college variables (Pace and Baird, 1966); and (3) variables useful for *understanding* the environment and those useful for decision making (Baird, 1971; Cain and Watts, 1970). The present study seems to focus on variables potentially useful for decision making, but it does not treat *within* college experience variables (working, and so on) differently from *between* college variables (enrollment, and so on). (This is related to the problem of the unit of analysis, to be discussed in a moment.) I think the study would have been made much stronger if some of the variety of other *between* college measures had been used, such as those in Astin's 1965 book, or those available through the American Council on Education's data bank. The variety of information is too great to be discussed here, but many of the variables would have policy implications.

Let me observe that it is quite striking that virtually every approach that has been used to study college environment has been basically empirical, lacking anything but the vaguest of implicit theoretical ideas. It would be useful to both researchers and decision makers to know not only *what* is happening in colleges but *why* it is happening, so that they will have a better basis for recommending or making decisions. This is not to fault the present paper in any way, but merely a wistful hope for better days ahead.

The problems of the fifth element, finding the most appropriate technical or statistical model for assessing efforts, is a topic of heated debate in research and statistical circles (e.g., Astin, 1970; Feldman, 1970). The literature and issues are too complex to go into in a brief time, but one issue seems more important than others—that is, the unit of analysis used in the data. As Astin (1970) has pointed out, there has been considerable controversy about the most appropriate use of multivariate analysis in analyzing student input, environmental, and student output information. Perl (along with such authors as Werts and Watley, 1969) pools all input and environmental variables in a single analysis rather than using a two-stage input-environment analysis—that is, developing some predictions based on student data, then, in a second stage, studying how institutions affect or add to those predictions, using either the college as a unit, or the student, depending on the question asked. The resulting regression coefficients in the single regression analysis are taken to reflect the "independent contribution" of various input and environmental variables in accounting for variation in the output variable. One interpretive difficulty with this method is that the various input and environmental variables may not be independent. As Astin (1970) writes: "The problem here is essentially one of what happens to the confounded variance. Since this variance must be reflected in the regression coefficients, there is no way to determine merely from these coefficients just how much of the confounded versus unique variance has been allotted to

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any independent variable or class of variables." (Of course, the study under discussion does try to develop different results for different groups of colleges, but this is a relatively costly and inefficient strategy.) Another problem is that the regression coefficients do not show whether a particular variable is acting directly on the output variable or whether it is operating primarily as a suppressor variable by accounting for extraneous variance in other independent variables.

These are difficult problems for which I have no perfect solutions, but I think the paper might take cognizance of them. However, several other methods may be useful, and should be mentioned. One method (Rock, Baird, and Linn, 1971) that seems to eliminate some of the problems of regression analysis is to: (1) develop regression lines for each institution, using the best predictors for the whole sample as variables; (2) use a grouping or clustering technique, such as Ward's (1963); (3) employ multiple-group discriminant functions using the regression lines as data, to see if colleges are in fact different; and, (4) employ discriminant functions using college descriptive measures. This seems to be one useful way to study the relative effects of colleges for the purposes of studying between-college effects. Another approach might be the use of path analysis (Blalock, 1964; Duncan, 1966).

This brings us to the sixth element, determining who is going to use the results of studies for what purposes. There are at least three groups of users of research results: the first is the private or public agency that would like aids for deciding which institutions or programs to support, and at what level. For these users, the institution or program might be the most useful unit of analysis, with between-college variables that have fairly direct monetary or policy implications emphasized. A second group of users of research results consists of the local administrator or decision maker who wants to alter his institution's environment so that it may be more effective in reaching the criteria he values. For these users, the unit of analysis may be programs within *and* between institutions, with variables that assess relatively specific aspects of the institution. The third user is the student who is choosing a college or a course of action within a college. In choosing a college he is not overly concerned about the policy implications of a measure but rather with whether it affects characteristics of the environment he is interested in or that are related to outcomes he values. Thus, using the college as a unit, the between-college measures can refer to rather subjective characteristics such as friendliness, as long as they are reliable and available for the colleges he is interested in. He may also wish to know the influences of working, for example, so he can guide his actions. For these, the unit of analysis may again be the within-college experience, perhaps analyzed across colleges with studies of the interaction of experience and between-college differences. Perl's paper seems to try to say something for each of these groups of users. It might be useful to focus the analyses for one of the purposes, rather than touching on all of them.

In this critique, I have tried to describe some of the complexities of studying institutional impact. I should repeat that no single paper can do all the things that I have mentioned. Overall, Perl's paper seems to be a useful contribution to the long-term enterprise of understanding how our higher education system works.

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Alvin K. Klevo

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Lewis Perl's paper "Graduation, Graduate School Attendance, and Investments in College Training" presents a new model of the production process in the college sector of the education industry. The model's novelty derives from the new measures of the output of the college production process and the new collection of measures of the inputs to the process that are used. Employing this model and a broad data base, derived from the Project Talent Survey and the Higher Education General Information Survey, Perl examines the relationship between the inputs to the college production activity and the educational outputs of that activity.

His empirical results are interesting. In particular, one welcomes the plausible but sometimes hard-to-find result that both individual-student and school-quality factors are important in the production process. Furthermore, as the author indicates, the results of this study have implications for educational policy decisions at several levels: the individual student, college administrators, and public educational policy makers. Because Perl intends his production-function results as a guide to these several sets of decision makers in their joint attempts to improve the efficiency of educational investment, it is most important that we examine carefully the model and the particular estimates upon which these recommendations are based.

1. THE MEASURES OF EDUCATIONAL OUTPUT

To begin, consider the measures of educational output used in the model: graduation and graduate-school attendance. One wonders whether these are adequate measures of the output of the college sector. Different degrees—differentiated by field, by school, and so on—are explicitly, or at least implicitly, given different weights when they are taken as measures of productive capacity. Even if one were to take the view, as some people have, that most productive training takes place on the job, it is still the case that the

NOTE: I am grateful to my colleague Kim Peck for his helpful discussions.

background characteristics with which an individual comes to a job will be evaluated by potential employers on the basis of what degree he has as well as whether or not he has a degree. The probability that the individual will get a particular job and his future earnings in that job will depend on the type of degree he has earned. But Perl's measure does not distinguish among different types of degrees.[1]

Stated in extreme terms, if we accept Perl's measures of educational output, and if, as a policy goal, we desire to increase that output, there is a very simple policy to follow. Specifically, all colleges should lower their degree standards and all graduate schools should lower their admission standards. At an individual level, ceteris paribus, it would be optimal for a student to attend a school whose admissions standards and degree standards were far below his own ability. One must wonder about an output measure with such implications.

Perl's output measure treats education of undergraduates as the production of a homogeneous commodity—graduates. In contrast, the agents in the education industry—both consumers and producers—view the industry as producing a collection of heterogeneous outputs—graduates of different quality.[2] The variation in school input levels observed in Perl's sample may be directly related to the multidimensionality of college education output that has been lost in his reduction of output to one dimension. And, the difference in the structure of his estimated relationship that emerges when the sample is divided according to the level of a particular input may be a reflection of the differentiated-product nature of this educational output. For example, if a degree from a small college is regarded as a product different from a degree from a large school, and if size of school is highly correlated with student-faculty ratio, then it could be the differentiated-product character of the output that led to differences between the structures of the regression for schools with high student-faculty ratios and for schools with low student-faculty ratios.

It is true that as economists we often simplify, especially in our empirical work, and regard products that differ in some attributes as the same product. But this reduction of all attributes to one seems highly inappropriate in the case of measurement of educational output. It is difficult to believe that any *one* index of output, and particularly attainment of a degree, will suffice to measure the output of the college sector of the education industry.

2. THE DETERMINANTS OF GRADUATION AND GRADUATE SCHOOL ATTENDANCE

Let us suppose, nevertheless, that one did want to measure the output of colleges by the number of degrees that were granted. What factors affect the probability of graduation for an individual student? Following Perl, the relevant elements can be divided into two categories: student factors and school factors. Among the student factors would be included (1) ability and (2) effort, with effort itself being a function of (a) motivation, (b) the time available for study, and (c) the student's living environment. While the author is very careful about his inclusion and his measurement of student ability, he pays no attention to student motivation. The student, however, undoubtedly arrives at college with some motivation, just as he arrives with some ability. The college can affect his motivation just as it can affect his ex post (after-college) ability (for which Perl uses grades as a proxy). It may be difficult to disentangle ability from motivation with the available data, but surely motivation requires some mention. In future studies of this type where students are given a battery of ability tests, perhaps it would be worthwhile to subject them as well to the tests psychologists have developed to measure motivation.[3]

The time a student has available for study and the nature of his living environment are probably strongly affected by the financial resources he has available. The author uses four variables to measure these dimensions of student input: (1) whether or not the student works, (2) how many hours a week the student works if he does, (3) whether or not he lives at home, and (4) the student's annual living expenses. Curiously, neither family income nor any measures of the scholarship aid the student is receiving or the amount he is borrowing ever enter the model constructed by Perl. Yet one would think that the entire financing picture—in particular, the way in which the student is raising the funds needed for his education and the extent of family financial resources—would affect the student's available time and his living environment and, hence, his probability of graduating. Indeed, Perl talks in several places (for example, page 00) about the student's financial capital and the importance of such capital in determining the success of his college-education investment. The information he uses concerning students' financial situations does not seem adequate to the conclusions he wants to draw.

Turning to those aspects of the individual school that affect the student's probability of graduation, one would include: (1) standards of admission, (2) standards of graduation, (3) resource inputs including both (a) instruction-related activities and (b) research and other noninstructional activities, (4) enrollment, (5) ability of other students, and (6) financial aid provided—both the total amount and the composition according to type of aid. Some comments are in order concerning the way in which the author treats several of these factors.

Perl notes that his output measure is quite subjective because standards of graduation may vary across institutions and may be an increasing function of the school inputs. He pays particular heed to this problem in discussing the differences between private and public colleges. Different schools do have different admissions and degree standards, and it seems clear that differences in these policies will have an important effect on the probability that a given student graduates. Hence, a study of the college education process that focuses on the role of student inputs and school resources should control for such differences in admissions and graduation standards. As a first approximation, this suggests the inclusion of two other independent variables

1. $$\frac{\text{number of graduates from student's entering class}}{\text{number of admissions in student's entering class}}$$

and

2. $$\frac{\text{average ability (at time of admission) of student's entering class}}{\text{average ability (at time of admission) of graduates from student's entering class}}$$

The author's treatment of the resources the college devotes to producing a graduate also raised some questions in my mind. First, I wondered why instructional expenditures per student and research expenditures per student were included as separate variables, each measured in dollar terms. Presumably, when measured in dollar values, these variables are highly correlated. If they are highly correlated, this might explain some of the difficulty encountered in obtaining significant plausible values for the expenditure parameters in the graduation regression. At the same time, Perl seems quite right in supposing that research expenditures and instructional expenditures have different effects on the graduation rate. But, then, why not measure the school's financial input by its total expenditure per student and have another variable measure the proportional division between instructional and research expenditures?[4]

It is also not clear why normalization of the instructional expenditures to reflect the level that would have obtained at a 20:1 student-faculty ratio is appropriate. The selection of (1) a level of instructional expenditures per student, (2) a level of research expenditures per student, and (3) a student-faculty ratio represents the choice of an education technique from the available education technology. The selection of a particular input triad should be considered an optimizing choice. Normalizing to a standard student-faculty ratio only obscures the different input combinations chosen by different schools. The particular normalization employed by the author would be appropriate only in the presence of certain types of education technology and no argument is presented that the actual technology takes such a form.

Two further points should be raised concerning the measurement of the college's resource inputs. First, since the paper is concerned with the output of undergraduate education, the appropriate data on expenditures and student-faculty ratios are data on the resources devoted to undergraduates and the undergraduate student-faculty ratio. It is not clear from the paper that the data available to the author were sufficiently disaggregated between undergraduate and graduate education to enable him to obtain the most appropriate figures. Second, one is almost always dubious about measures of student-faculty ratios. As Perl points out, he has made no effort to distinguish between faculty involved in resident instruction and faculty involved primarily in research or extension activities. An added difficulty results because different colleges report the status of teaching assistants and the like in different ways when computing faculty size. It is difficult, therefore, to know exactly how much teaching input to associate with a given student-faculty ratio.

3. THE PRODUCTION FUNCTION

Perl assumes that the output measures he employs are linear, additive functions of the inputs to the college education process he considers. He recognizes that such a model precludes the possibility that the productivity of an input depends upon the level at which it is employed or on the level of other inputs. To provide for some degree of nonlinearity, the author includes both a linear and a quadratic term in enrollment, and he estimates the parameters of his model separately for subsamples in which the range of particular inputs is restricted. These separate estimates seem quite suggestive of important complementarity relationships among inputs to the college education process. I would have preferred to see more explicit account taken of these interactions.

My own prior belief is that it is far more likely that marginal rates of substitution between education factors vary with changes in input levels than it is that these rates of technical transformation are constant. Some multi-input Cobb-Douglas production function would seem to me to be a more appropriate model. Alternatively, one might have chosen an intermediate position. First, an aggregate student input would be formed as a linear combination of the student factors and an aggregate school input would be formed as a linear combination of the school factors. Then, the two aggregate inputs would enter a two-factor Cobb-Douglas function. In any event, nonlinearities in the educational production process—both in terms of diminishing returns to a single input and in terms of substitute-complement relations between inputs—seem important, and they deserve more explicit attention than the author's model has given them.

4. THE ESTIMATION TECHNIQUE

In estimating his linear additive model, Perl uses a two-step procedure to correct for the heteroscedasticity resulting from the dichotomous nature of his dependent variables. While this two-step regression procedure provides efficient estimates of the parameters of his linear probability function, there remains an important problem with the use of the linear probability function model.[5] Specifically, this model allows EY_i (the conditional probability of graduation or of graduate school attendance, given the input vector X_i) to lie outside the range [0,1]. This is, of course, inconsistent with the definition of Y and with the interpretation of EY_i as a probability. There will be vectors of inputs, X_i, for which the conditional probability of graduation $EY_i = X_i' \hat{\beta}$ is greater than one and others for which it is less than zero. There may even be vectors of inputs in the sample itself for which the estimated conditional probability $\hat{Y}_i$ will not lie in the [0, 1] interval. It would seem that the appropriate statistical model to employ in the case of Perl's production function with a dichotomous output measure is multivariate probit analysis.[6] This is a maximum likelihood estimation method that takes explicit account of the dichotomous nature of the dependent variable and that ensures that EY_i is restricted to the [0,1] interval.[7]

5. MULTICOLLINEARITY AND THE INTERPRETATION OF THE EMPIRICAL RESULTS

Let us, finally, consider some of the difficulties that may confront us in interpreting Perl's results and in attempting to convert these results into policy recommendations. The major difficulty arises because one suspects that there exists a high degree of collinearity among the measures of school inputs. The author confirms this suspicion for private colleges when he cites the collinearity problem as a probable cause of the less satisfactory performance of his private-college equation. In addition, he shows us that when the sample is stratified by the level of some specific school input—for example, student-faculty ratio or instructional expenditures per student—it turns out that colleges that are high (low) input on this criterion are also high (low) input in terms of the other school factors. While this evidence does not confirm any suspicions of collinearity, it surely strengthens those misgivings. If, indeed, there is a high degree of collinearity among the inputs to the education process, it is of course difficult to disentangle the effect of particular inputs and any policy recommendations are placed on a somewhat less-than-solid foundation.

The collinearity problem is perhaps exacerbated by the way in which the author selected the principal components of ability to include in his final analysis of the production of graduates and graduate school attendance. First Perl regressed each output measure on all twenty-two ability components and all the other exogenous variables (the nonability student inputs and the school inputs). He then retained for use in the final analysis only those ability components that had a "substantial effect" in the preliminary regressions. By definition, the omitted principal components are orthogonal to those retained, and hence there is no chance that the explanatory power of the components excluded from the final analysis is shifted to the retained components. But if the nonability exogenous variables are correlated with the omitted principal components of ability and if these omitted components were contributing any explanatory power in the preliminary regression, then the final regressions will impute too much importance to the nonability exogenous variables.

One last caution may be in order for the policy maker who would base his recommendations on the results of the present paper. To ensure that his

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sampling from any one college was reasonable in size, Perl required that each student in his final sample attend a college attended by at least ten other students who (1) were in the original Project Talent sample and (2) responded to both follow-up questionnaires. This exclusion of all colleges having fewer than eleven students in the modified Project Talent sample in its student body probably yields a bias against small colleges. To the extent that this bias exists and to the extent that college characteristics other than enrollment differ systematically between small and large colleges, the regression results may be misleading in their implications for the efficacy of certain policy measures.

6. A CONCLUDING COMMENT

In summary, Perl has provided us with an interesting new model of the college sector of the education industry. As with anything novel, however, there are some serious questions about the innovations that must be answered before we are willing to buy and to use the product.

NOTES

1. For example, his measure draws no distinction between "degree mills" and other institutions. While such distinctions are difficult to make, they have been found necessary and they have been made, for example, in the Bundy plan for New York State aid to private colleges.
2. This statement of producers' concerns already ignores the fact that universities may view themselves as having more than the education of undergraduates as their goal. They are also concerned, for example, about the contributions they make to scholarship, their production of Ph.D.'s, and so on.
3. For example, one might use the tests developed by David McClelland and his associates to measure need for achievement.
4. This procedure was actually used by Perl in his preliminary regression (Table A-1), which included all twenty-two ability components. One wonders why it was not used in the final regression as well.
5. For a more complete discussion of the linear probability function, see Arthur S. Goldberger, *Econometric Theory* (New York: John Wiley and Sons, 1964), pp. 248–251.
6. For a description and discussion of this procedure, see James Tobin, "The Application of Multivariate Probit Analysis to Economic Survey Data," Cowles Foundation Discussion Paper No. 1, 1955.
7. It should be noted that in an appendix to his paper, Perl uses logit analysis to reestimate the relationship between the output of the college education production process and the inputs to that process. Specifically, he groups his data by college and estimates the parameters of a linear relationship between the student and school inputs to college education and the log odds of graduation (or graduate school attendance). The logit-analysis approach does avoid some of the statistical and conceptual problems created by the linear probability function. Had Perl been willing to use nonlinear estimation techniques, however, he would not have had to group his data by college. That is, using nonlinear estimation procedures and a particular specification of the error term would have enabled the author to retain the individual student as his unit of observation. This would have provided him with parameter estimates that were more directly comparable with his original estimates for the linear probability function.

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