1987

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Robert C. Dolan
University of Richmond, rdolan@richmond.edu

Robert M. Schmidt
University of Richmond, rschmidt@richmond.edu

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ECRSB-87-1

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Robert M. Schmidt

Associate Professors
Department of Economics,
E. Claiborne Robins School of Business
University of Richmond, Virginia 23173

This material is based upon work supported by the National Science Foundation under Grant No. SES-85 10751. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the National Science Foundation.

This study examines the input-output relationship for private undergraduate education. The objective is to identify the relative contributions of human and physical resources in the production of quality undergraduate education. The research methods are noteworthy in three general respects. First, the theoretical orientation emphasizes interdependence among inputs and outputs in higher education. The significance of simultaneity is demonstrated in an empirical model estimated via a three-stage least-squares technique. Second, the study introduces an original and promising data set for research in higher educational production. Of special note is an index of output reflecting the quantity and quality of institutional production. Finally, the exclusive emphasis on private undergraduate institutions offers a well focused perspective for policy decisions in higher education.

The conceptual and empirical extensions presented in this study expand the basis upon which educational research can proceed. Further, the results have useful implications regarding the allocation of institutional resources across the basic inputs in higher educational production. Thus, the study directly addresses the current concern for a better understanding of the interactions among student quality, faculty quality, and institutional resources as they combine to produce undergraduate education.

The report is organized as follows. Section 1 discusses the focus and contribution of this research in relation to the economics literature. Section 2 specifies a simultaneous model of educational production. Section 3 describes the data, variables, and estimation procedures. Empirical results appear in Section 4. Section 5 presents concluding remarks and suggestions for future research.

1. Focus and Significance

This study falls generally within the economics literature which has analyzed the educational process via a production function specification. While this literature is extensive, the vast majority of empirical investigations have been limited to primary and secondary education. The official beginning of the educational production literature is commonly associated with the publication of the federal study, *Equality of Educational Opportunity* (1966). The Coleman Report, as it is more popularly known, sparked a series of efforts to identify empirically the relationship between resources and student achievement.[1] In contrast, remarkably little attention has been given to the production relationship in higher education. As Hanushek (1986) notes,

> Economic studies of higher education have been largely concerned with distributional questions related to access and costs faced by different groups ...; virtually no attention has been given to production processes or the analysis of specific programs. (p. 1143).

Perhaps the major factor accounting for the relative dearth of production studies in higher education is the complexity introduced by joint production. It is generally agreed that higher education, and universities in particular, produce three outputs jointly -- instruction, research, and public service. Although the literature contains some interesting efforts to address the joint-product dimension of higher education, modeling in this

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[1]Averch et al. (1972) present the most comprehensive review of the early literature after the Coleman Report. An important survey and discussion of the concept of an educational production function is given by Hanushek (1979). Some inkling of the extraordinary number of empirical analyses at the primary and secondary level is also provided by Hanushek (1981). That article contains a broad overview of no less than 130 studies.

area is clearly in its nascent stage.[2] Given this fact, it is expedient to limit the present study to undergraduate institutions; such a focus justifies a simpler, single-product emphasis on instruction in specifying a model of educational production.

The empirical base for this study is further limited to private schools. The analytical advantages of this tack are threefold. First, eliminating public schools buttresses the single-product emphasis by minimizing the public-service mandate. Second, restricting the sample to private schools serves as a broad means of controlling for socioeconomic effects when examining educational production across institutions. Third, this focus lessens the need to model behavioral relationships among faculty, administration, and government arising out of factors more common in public education (e.g. unions, legislatures). The potential significance of these relationships in revamping public educational policy has been discussed by Hanushek (1981).[3] Although Hanushek develops this point explicitly in the context of primary and secondary education, it is clear that political objectives and constraints also profoundly influence the character of public

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[2] Theoretical discussions of university joint production are Nerlove (1972), Becker (1975), Garvin (1980) and Hopkins and Massy (1981). Southwick (1969) and Sengupta (1975) are rare examples of empirical attempts to consider the joint-product nature of university production. However, their reliance on enrollment and research expenditure as output measures diminishes the value of these empirical efforts. In a recent survey, Hopkins concludes that "the current state of understanding of the interactions (i.e., joint production) -- at least in any quantitative sense -- is quite rudimentary" (1986, p. 16).

[3] Hanushek suggests that policy efforts to enhance output may need to be more sensitive to the incentive structure and political economy of the public school system, perhaps drawing upon theories of rent-seeking behavior central to the public choice literature. For a collection of the seminal literature on rent seeking, see Buchanan, Tollison, and Tullock (1980).

university production.[4] In comparison, private education would seem to accommodate a far more straightforward treatment of student, faculty, and administrative behavior. In essence, the focus of this study is confined to private undergraduate education for analytical convenience and clarity. This submarket, due to its relatively homogeneous character (private) and product specificity (instruction), is probably the simplest, and yet quantitatively significant, segment of higher education for which the production relationship might be empirically tractable at this time.

The contributions of this research are both empirical and conceptual. Perhaps the most intriguing aspect of the study is the method of quantifying educational output at the institutional level. Production across baccalaureate schools is measured as the number of alumni who later receive Ph.D.s, M.D.s, or J.D.s. Measurement by institution in this fashion has important implications.

Typically income or achievement test scores have been used as a proxy for educational output. Because these data are specific to individuals rather than institutions, previous studies have tended to identify factors that affect individual achievement within a single school system or college. In such a setting, all students face similar institutional characteristics. As a result, differential effort and social background of the individual student largely account for variability in student achievement. However, variance in the latter factors should become less pronounced when comparing output across undergraduate colleges, and perhaps especially

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[4] For state universities, legislatures are not only a major factor in determining total budgets, they also review tuition and student access policies. Recent analyses of these issues in modeling the public university are provided by Hoenack (1983) and Hoenack and Pierro (1985).

so given the previously noted focus on private schools. Instead, the impact of differences in institutional characteristics -- student quality, faculty quality, and per capita expenditures on various facets of education -- can come to the fore. For this reason, policy inferences are attuned to institutional parameters rather than the characteristics of individuals.

Indeed, it is somewhat surprising that this study represents a relatively rare case of analysis across institutions. Most production studies of higher education have examined an individual school or selected department.[5] With the exception of the authors' earlier note (1985), only Astin (1968) has looked at undergraduate education across institutions, and even Astin's study relies on a relatively small sample of 32 schools. The present study examines institutional production based on the output and characteristics of roughly 360 private undergraduate schools. Again, this comprehensive cross-sectional view at the institutional level is useful because it offers policy implications geared directly to managing institutional variables. Such policy inferences seem particularly important considering the fact that so many of the variables influencing educational achievement are believed to be socioeconomic and student-specific, and thus often lie outside the policy realm.

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[5] Breneman (1976), Perl (1976), and Hogan (1981) have examined the production of Ph.D.s within a graduate department or institution. Clearly, these authors have also chosen to focus on a single university output, although they opt for the graduate end of the instructional spectrum. Manahan (1983) examines undergraduate instruction, but only within a specific major and institution. Lewis et al. (1985) discuss the empirical literature of educational production in relation to computer-assisted instruction, but here again the focus is specific to an individual classroom or departmental experience.

The alumni achievement index has the special merit of capturing the quality and quantity of a school's production. This output measure is quality-adjusted in two respects. First of all, the explicit emphasis on alumni success in relatively selective professional careers imparts a qualitative dimension in and of itself. Stated differently, this output measure reflects academic production at the higher end of the achievement distribution. This focus deviates markedly from the common, and perhaps inordinate, emphasis on average measures of academic achievement in efforts to identify the relative productivity of various educational inputs.[6] Thus, concentration on professional careers is in itself a quality adjustment within a quantitative variable. A second dimension of quality adjustment exists within the index with respect to Ph.D. alumni. An algorithm has been constructed that weights each alumnus Ph.D. by the quality of the specific graduate program from which that alumnus received his or her Ph.D. degree. In short, the Ph.D. component of an institution's output will be measured as the number of Ph.D. alumni produced, adjusted for the quality of the graduate program each attended. In relation to the literature, these qualitative dimensions of the output index appear quite significant. One of the most common and serious criticism expressed in reviews of the educational

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[6]Astin (1973) has discussed this point at length. He emphasizes that any evaluation of efficiency in producing educational outcomes must be sensitive to effects throughout the entire achievement distribution, not simply in respect to improvements in mean academic performance. Astin interprets the traditional approach as reflecting an "egalitarian" definition of efficiency in educational production. In contrast, our emphasis might be thought of as attempting to identify efficiency in "elitist" production. Given the recent concern for U.S. competitiveness and the critical nexus to education, it would seem increasingly appropriate to examine educational strategy from the latter standpoint.

production literature is a general inability to quantify educational production in a manner sensitive to quality differences in output.[7]

On a conceptual level, the model developed in this study is noteworthy for its emphasis on interdependence among inputs in institutional production. For example, the purchaser of the product -- the student -- is also one of the more important inputs. Similarly, the quality of the faculty is likely to be causally related to the quality of several other institutional attributes believed to contribute to output, not the least of which is student quality. The important modeling implication is simply that the production relationship is far more complicated than the input-output specification commonly found in the literature.[8] To address this issue, we develop a three-equation simultaneous model in which the quality of college output, faculty, and students are treated endogenously. The model is then estimated with three-stage least-squares estimation.

In sum, this study develops a unique measure of institutional output within a relatively rare, yet conceptually appropriate, theoretical and statistical framework. Using alumni achievement, we attempt to measure the quantity and quality of output at the institutional level, while modeling the process with due consideration for the significance of simultaneity among inputs. The result of this approach is an improved method for assess-

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[7] For example, see Hopkins and Massy's book (1981), especially Chapter 3.

[8] McGuckin & Winkler (1979, pp. 242-43) make a similar argument in their intra-university analysis. They emphasize that although all students have access to the same potential level of university resources, students realize that potential at widely disparate rates. Their results show that studies which treat resources exogenously understate their role in determining student achievement. The relevance of simultaneous estimation in educational modeling is also raised by Summers and Wolfe (1977) and Hanushek (1979), although this issue is not the focus in these articles.

ing the impact of varying factor proportions on educational output. Furthermore, the empirical focus of this research offers policy recommendations directly operational at the institutional level.

Before turning to the body of this report, one prefatory comment is pertinent, if not obligatory. It is widely acknowledged that the term "production function", though tempting nomenclature, is technically inapplicable to this genre of research. Economists reject the label in the sense that learning theory has yet to provide a well-defined technology of education. Without such a foundation, theorists are hesitant to invoke Shepard's (1953) duality principle. It is Shepard's theoretical proof that permits inferences about the efficiency of production relationships to be drawn from empirical studies of cost data. Accordingly, cost theory becomes a means by which to assess the output implications of varying factor proportions. Although we certainly acknowledge the correctness of this point, it may also be unduly arcane in a practical sense. We side with Cohn who concludes that any enhanced understanding of the economics in this area will necessarily be advanced in small steps.[9] Acknowledging that a large theoretical gap exists in defining the efficient frontier in education production, we would still argue that existing cost data can be useful in revealing input strategies to improve educational production, even if that struc-

[9] See Cohn (1979), especially pp. 188-205. For a more critical view, see Levin (1974). In essence, Levin argues that schools are inherently inefficient and therefore useful policy inferences cannot be gleaned from cost analysis. A similar perspective is expressed by Bowen (1980) in his "revenue theory of cost", i.e. colleges cost-maximize subject to their ability to raise revenue. Brinkman's recent paper (1986) includes a concise summary of this issue. His conclusions are supportive of our position.

ture itself cannot be rigorously shown, or even suspected, to reflect the efficient production surface in the pure sense.

2. The Model

The production relationship in education typically expresses output (e.g., income or GRE scores) as a function of resources (e.g., faculty, capital plant, endowment) and student characteristics (e.g., SAT scores, family background data). In functional form,

$$Q = f(R,S) \tag{1}$$

where Q, R, and S denote output, resources, and student characteristics. However, this rendering of the production function ignores the fact that two of the more important inputs, students and faculty, enter the process upon considerable self-selection, especially among the more highly qualified of these inputs. Conceptually, a model of higher educational production should reflect the broader perspective that the quality of output can influence the quality of inputs, and that certain institutional resources may themselves enhance the quality of the inputs. This reasoning suggests the educational production process is more appropriately cast as a simultaneous system in which the quality of students, faculty, and college output are treated endogenously.[10] To address this interdependence, Equation (1) is respecified as the following three-equation simultaneous system:

$$\Gamma y_i + \beta x_i = u_i \tag{2}$$

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[10]This three-equation system represents the minimal level of simultaneity necessary to model the higher education process. An intriguing extension would be to model explicitly an administrative objective function as well. In its present form, the model implicitly presumes that institutions attempt to maximize quality while recognizing input tradeoffs. Further discussion of this issue is provided in Section V.

where y_i = a vector of three endogenous variables for school output (Q), student quality (S), and faculty quality (F).

x_i = a vector of 25 exogenous variables, each generally representing institutional characteristics (e.g., tuition, endowment, plant).

Γ = 3x3 matrix of endogenous variable coefficients.

β = 3x25 matrix of exogenous coefficients.

u_i = a vector of three error terms assumed to be distributed normally with zero mean and constant variance. Errors may be correlated across equations.

i = observation index for 361 private, undergraduate-oriented universities. These are schools which do not grant doctorates, but may have master's programs and possibly a law school.

Implicitly the model is written:

$$Q = f_Q(\underset{+}{S}, \underset{+}{F}, \underset{+}{K}, \underset{+}{AC}, \underset{+}{AD}, \underset{?}{RE}, \underset{+}{FSR}, \underset{+}{ISR}, \underset{+}{USR}, \underset{?}{CURR_{1-4}}, \underset{+}{\%MSTUD}, \underset{-}{\%BUS}, \underset{-}{\%ENG}, \underset{-}{\%ED}, u_Q) \quad (3)$$

$$S = f_S(\underset{+}{Q}, \underset{+}{F}, \underset{+}{K}, \underset{+}{AC}, \underset{?}{T}, \underset{?}{SCH}, \underset{?}{\%SCH}, \underset{+}{FSR}, \underset{+}{ISR}, \underset{+}{USR}, \underset{?}{CAMPUS_{1-4}}, \underset{+}{CURR_{1-4}}, \underset{?}{\%MSTUD}, u_S) \quad (4)$$

$$F = f_F(\underset{+}{Q}, \underset{+}{S}, \underset{?}{K}, \underset{?}{AC}, \underset{?}{RE}, \underset{+}{E}, \underset{?}{FSR}, \underset{-}{ISR}, \underset{-}{USR}, \underset{+}{\%MFAC}, \underset{+}{\%TEN}, \underset{+}{\%BUS}, \underset{+}{\%ENG}, \underset{-}{\%ED}, u_F) \quad (5)$$

where Q is an output index reflecting the number of alumni Ph.D., M.D and J.D. recipients;[11] S denotes student quality defined as the third-quartile SAT score of the entering freshman class; and F is faculty quality as reflected by average compensation at the associate professor rank. The compensation data are adjusted for interstate cost-of-living differences. A notational key to Equations (3) - (5) is presented in Table 1. More detailed descriptions of the variables, construction of the output index, and cost-of-living adjustment are deferred until Section 3. The focus of this section is to develop the theoretical basis for each of the equations. Note that the predicted sign (+, -, ?) for each partial relationship appears under the variable.

Equation (3) posits that successful alumni are the product of quality human (S, F, AD) and nonhuman (K, AC) resources. The nature (USR) and intensity (FSR) of the undergraduate instructional atmosphere are also deemed important in fostering success at the graduate level. Equation (3) includes four indices based upon dimensions of a school's academic program ($CURR_{1-4}$). These indices reflect curricular offerings such as honors programs, independent study, double majors, study abroad, and internships.

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[11]Given the admittedly diverse nature of the respective career paths contained in the output measure, it is logical to wonder whether a factor analysis of these components might be a useful rendering of the quality of institutional production. We experimented along this tack, but found little change in the results obtained from the simple summation of the career components in Q. We were also intrigued about the applicability of LISREL (Joreskog and Sorbom, 1984), a similar yet higher order procedure for applying weights to indicators of an unoberservable variable within the overall structure of a simultaneous system of equations. This approach proved inappropriate, however, because the LISREL estimates are highly sensitive to the structure of the model. For reasons discussed in the concluding section, we would prefer to refine the system's structure before applying a full-information maximum likelihood technique such as LISREL.

Table 1: Summary of Variable Notation

Q	Output Index (#Ph.D., #M.D.,#J.D.)	USR	Undergraduate Specialization Ratio
S	Student Quality	FSR	Faculty/Student Ratio
F	Faculty Quality	ISR	Instructor/Student Ratio
K	Capital Stock	$CAMPUS_{1-4}$	Campus Life Indices
AC	Academic Expense	$CURR_{1-4}$	Curricular Program Indices
AD	Administrative Expense	%MSTUD	% Male Student Body
RE	Research Expense	%MFAC	% Male Assoc. Professors
T	Tuition	%TEN	% Tenured Senior Faculty
SCH	Scholarship Expense	%BUS	% Business Majors
%SCH	% on Scholarship	%ENG	% Engineering Majors
E	Endowment	%ED	% Education Majors

Although one may be inclined to assign positive partial relationships to each of these curricular indices, there is in fact some ambiguity. Therefore, we withhold prediction regarding these curricular coefficients until the discussion of their construction in Section 3.

The remaining variables in the output equation (3) are control variables warranted largely by the unique nature of the output measure. For example, including a school's percentage of male students (%MSTUD) adjusts for the possibility that M.D.s, J.D.s, and Ph.D.s have been male-dominated degrees. Similarly, the percent of business (%BUS) and engineering (%ENG) majors controls for the likelihood that these alumni are more often terminally qualified in a career respect, and thus less likely to progress toward doctoral degrees vis-a-vis the alumni from equal-quality schools which are more exclusively devoted to the arts and sciences. The percent of education majors (%ED) is also a control, but for the somewhat different reason that the output variable constructed in this study does not encompass doctoral degrees in education.[12]

Equation (4) presents a reduced-form modeling of a somewhat complicated market -- the market for student quality as measured by SAT. Viewed as an input, students supply, and colleges compete for, the quality necessary to enhance institutional reputation. The market roles are then reversed in terms of the educational product; students are the demanders and universities the suppliers. It turns out, however, that the predictions for many of the variables are unaffected by this complication since quality students are drawn, and vied for, via reputation. This broad concept of quality is reflected collectively by alumni achievement (Q), faculty quality (F), physical plant (K), academic expenditure (AC), and factors indicating emphasis on the student (FSR, ISR, USR, $CURR_{1-4}$). Thus, the predicted signs are all positive.

The relationships for the remaining variables in the student equation are less clear. The scholarship variable (SCH) illustrates this ambiguity. Although one might generally view financial aid packages as an effective mechanism to "buy" better students, Ehrenberg and Sherman (1984, p. 213) found a relatively low elasticity on the ability of scholarship increases by Cornell to draw the highest quality applicants away from schools revealed by students' acceptance decisions to be even more prestigious. Based on this finding, one must infer a consumer surplus at the preferred schools in

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[12] Education Ph.D.s had to be excluded because doctoral programs in this area are not covered in the Jones-Lindzey study of graduate school rankings. For the same reason, the output measure also excludes doctorates in health sciences, business administration, meteorology, communications, and agriculture.

excess of scholarship differentials. Should this elasticity be equally low among the schools examined in this study, the linear nature of the estimated model could evince a negative coefficient for SCH. Therefore, the predicted sign for the student aid variables is unclear.[13] Tuition (T) is another variable with similarly subtle implications for modeling the quality dimension. A high tuition should be a deterrent to all students for an equal-quality product. However, if tuition reflects real or perceived quality differences not adequately accounted for by other variables in the model, then tuition might exert a positive influence for better students. The net effect of $CAMPUS_{1-4}$ offerings is unclear. While a wide variety of activities might draw more student applicants, they will not necessarily draw better ones. Finally, the proportion of male students (%MSTUD) is included as a control for the possibility that males who go on to college have different SAT characteristics than do females. In sum, the hypothesized signs for the SCH, %SCH, T, $CAMPUS_{1-4}$, and %MSTUD coefficients in the student equation are ambiguous.

Equation (5) employs the average associate professor's compensation, adjusted for interstate cost-of-living differences, as a measure of faculty quality. Compensation was chosen because of its availability and objectivity of measurement. Furthermore, given the undergraduate-oriented sample of schools, this measure is not appreciably affected by rewards for quality research or higher salaries of medical and legal faculty. We submit that

[13]Of course, this discussion presupposes that scholarships are used to attract top-quality students in the academic sense. But clearly this needn't be true for many schools. Scholarships are often granted for performing talents -- dance, music, athletics -- some of which may not correlate positively with academic potential. Furthermore, some portion of scholarship students are need, rather than merit, based.

compensation is the institution's primary means of attracting and retaining quality faculty in the long run. The associate rank was chosen because these faculty are old enough to have established their credentials yet young enough and mobile enough to take advantage of them.[14]

Equation (5) should be viewed as a reduced-form equation of a supply-and-demand system for faculty quality. On the supply side, quality faculty prefer working with potential progeny (Q) and good students (S), *ceteris paribus*. On the institutional demand side, three control variables are included to adjust compensation differentials which are unrelated to faculty quality. The percent of undergraduate majors in business (%BUS), engineering (%ENG), and education (%ED) -- assuming these approximate faculty composition reasonably well -- are included as proxies for compensation differences attributable to different market conditions for faculty in quasi-professional versus more traditional academic disciplines. A tilt toward business and engineering faculty is expected to increase the average associate compensation, faculty quality held constant. In contrast, a high proportion of education faculty is predicted to decrease an institution's average compensation. By similar reasoning, schools with low undergraduate specialization ratios (USR) are predicted to have higher average compensation because of the higher salaries paid to graduate professors, particularly in law or medicine.

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[14]Reestimation of the system using assistant in place of associate professor salaries yielded very similar results in an earlier study. This is not surprising in light of the high correlations between salaries at the various levels -- assistant and associate, 0.90; associate and full, 0.95; and assistant and full, 0.83.

The remaining variables in Equation (5) reflect both supply and demand considerations. The size of an institution's endowment (E) represents financial security to faculty and ability-to-pay by institutions, both clearly positive influences. However, other important variables have off-setting effects and thus indeterminant predictions for the reduced-form coefficients. For example, although faculty might prefer better physical facilities (K) and higher academic expenditures (AC), institutions might view these inputs as substitutes for faculty. And while faculty prefer higher research support (RE) and smaller classes (FSR), administrators might see these factors as income-in-kind. Therefore, the signs on these variables are ambiguous *a priori*, even though the actual results for these relationships are of obvious policy significance.

On a more technical note, each equation is overidentified through the use of zero restrictions. Generally, an exogenous variable is excluded from an equation when there is no conceptual justification for its inclusion other than its influence on another endogenous variable. For example, consider our modeling of the endowment variable beginning with the output equation (3). Although the size of a school's endowment might alter output, its effect is really one of facilitating capital expansion, scholarships, faculty compensation, and so forth. Therefore, the latter variables are selected for the output equation rather than the value of the endowment itself. Similarly, the endowment is excluded from the student-quality equation since the manifestations of a large endowment (capital plant, faculty size and quality) are more visible to students than is the endowment itself. In contrast, however, recall that the endowment does appear in the faculty equation because of this variable's implication for an institution's longer term financial security and thus a direct consideration of faculty. Another example of the general modeling criterion underlying identification of the system is the inclusion of tuition, research expenditures, and scholarships as factors influencing student and faculty decisions, but not output, *ceteris paribus*.

3. Data and Estimation Procedures

The model outlined above is an extension of the theoretical framework developed by the authors in an earlier article (1985). The results of that research confirmed the strength of interdependencies existing among the endogenous variables as well as the importance of correcting for errors correlated across equations. Accordingly, the present estimation retains the modeling perspective of our earlier work. However, the current study substantially expands the sample size and refines the operational definition of several variables.

3.1 Quality Adjustment to Output

As emphasized in Section 1, perhaps the most intriguing improvements occur within the output measure. The revised output variable adds breadth and depth to the concept of alumni achievement as a measure of college production. First, the original focus on Ph.D. alumni is expanded to encompass M.D. and J.D. degrees. Furthermore, the Ph.D. component itself is now constructed to reflect differences in graduate program quality.

The quality-adjusted Ph.D. component of the output variable is a weighted sum of each baccalaureate school's doctoral alumni. The weight attached to a doctoral degree is based on the scholarly quality of the respective program's graduate faculty. The quality ratings are those developed by Jones, Lindzey and Coggeshall (1982).[15] The weights reflect an ordinal scale ranging from zero to five.[16]

Formally, the quality-adjusted Ph.D. output variable is defined as:

$$JLC_i = \frac{\sum_{j=1}^{n_i} (JLC_{dg})_j}{n_i}, \quad \text{and} \tag{6}$$

$$Q_i = n_i \left[\frac{JLQ_i}{\overline{JLQ}} \right] ; \tag{7}$$

where: i denotes a baccalaureate institution.

j denotes a graduate of the *i*th baccalaureate institution who received a Ph.D. between 1971-1980 in any area of the biological sciences, physical sciences, mathematical sciences, social sciences, or humanities.

n_i denotes the number of students from the *i*th baccalaureate school who went on to receive a Ph.D. in the above-mentioned fields.

JLC_{dg} denotes the Jones-Lindzey-Coggeshall rating of the graduate program attended by the *j*th student. Program ranks are specific to discipline (d) by graduate school (g).

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[15] This five-volume study surveyed several program attributes as they existed between 1976-1980 (e.g., size, library, research, reputation). The primary criterion for inclusion in the study was that a program had to have awarded some minimum number of doctoral degrees between 1976-1978. The minimum varies substantially across disciplines (e.g. 11 in History versus 22 in Psychology). For more information on the origins of the study, selection criteria, and methodology, see Parts I and II of any of the five volumes.

[16] Evaluation of faculty scholarship was assessed in a peer review survey. Evaluators were provided with a list of each program's faculty and asked to judge the group as distinguished, strong, good, adequate, or marginal. A copy of the survey instrument can be found in any of the five volumes of Jones, Lindzey, and Coggeshall (1982). Generally, the majority of respondents were full professors. The number of respondents also varied by discipline (e.g. 152 in History, 185 in Economics, 280 in Psychology).

Equation (6) calculates an average JLC ranking for all n_i of a school's Ph.D. alumni. Equation (7) weights the number of Ph.D. alumni by relative Ph.D. program quality. Division by the sample mean JLQ_i serves to rescale this quality index to a mean of unity, thereby retaining comparability of output measures across Ph.D., M.D., and J.D. alumni.

Table 2 presents a descriptive summary of the coverage of the JLC program ratings, by discipline, in relation to the doctoral degrees received by alumni for this sample of baccalaureate institutions. Observe that program-specific JLC ratings are directly applicable for 27,178 alumni graduate degrees. This represents a coverage rate of 79.4 percent. Regarding the remaining degrees, two general circumstances required that certain program ratings be assigned.

First, rarely are all the Ph.D. programs in any particular discipline evaluated. Rather, the ranking is often lower-end truncated. For example, of the roughly 130 Ph.D-granting programs in Economics, only the top 91 programs are evaluated in the JLC study. In such instances, we assume that unranked programs are necessarily of the lowest quality, and therefore are assigned a rating equal to that of the lowest rated program in the specific discipline. In terms of actual JLC values, this procedure implies that unranked programs typically receive a quality rating in the range of 0.4 to 0.7 out of a possible 5. This assignment was applied to 3,174 Ph.D degrees, which is 9.3% of the Ph.D.s received by alumni of the baccalaureate institutions in the sample.

Table 2: **Coverage of JLC Doctoral Program Quality Ratings for Degrees Received Between 1971-1980 by Graduates of Baccalaureate Institutions**

Field	Rating = JLC Rating	Rating = Minimum JLC Rating	Rating = Average Program JLC	Rating = Missing
Biological Sciences	3386	1002	1853	129
Mathematics & Computer Science	1307	185	46	3
Chemistry	3271	237	0	0
Physics & Astronomy	1566	166	0	0
Psychology	4868	577	0	0
Economics	1202	94	0	0
Political Science	1353	175	0	0
Sociology	1566	52	2	2
History	2319	152	0	0
Letters	3307	249	412	10
Foreign Languages	1075	115	235	12
Other Humanities	1958	170	1017	165
Total	27,178	3,174	3,565	321
Percent	79.4%	9.3%	10.4%	0.9%

The second case of fitted Ph.D. ratings occurs when none of the graduate programs in a particular field specialty are evaluated. Ratings for field specialties not evaluated are assigned the program's average rating of related fields within the broader graduate discipline. For example, the Parasitology degree at Stanford, a non-rated specialty, is assigned the average of Stanford's rated biological sciences programs. Although we are comfortable with this assignment algorithm generally, we believe that if a systematic bias exists, it probably operates toward understating program quality in those fields.[17] Overall this procedure applied to 3,565 degrees (10.4%), although as Table 2 indicates, it is used disproportionately in the specialized subfields of the biological sciences and humanities. In comparison, note that coverage by the JLC ratings in Chemistry, Physics, History, and the Social Sciences in general is remarkably complete.

Although the JLC ratings are quite comprehensive with respect to the disciplines listed in Table 2, not all doctoral-granting disciplines were evaluated in that study (e.g., education, communications, meteorology, business, agriculture, and health sciences). Therefore, baccalaureate alumni holding doctoral degrees in these areas are not included in the computation of their school's Q_i.[18] We have mixed feelings about the quantitative

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[17] This tendency seems likely since fields not evaluated usually reflect very specialized degrees awarded by relatively few institutions. Considering the level of specialization, one would expect the quality of the faculty scholarship to be at least equal to the average of the related rated programs in the graduate school.

[18] The obvious alternative to omitting the data is to assign ratings to these degree programs based on an average-quality concept analogous to that applied in the case of missing biological specialties within biological sciences. We would argue, however, that such an extrapolation strains the concept. While the average quality of the biological science departments may serve as a proxy for subspecialty merit, it is unclear why the average

significance of these missing disciplines. Taken together, the omitted disciplines account for 16,262 of the total 52,327 Ph.D.s received by alumni in the sample of baccalaureate schools. This implies that an alarming 31 percent of the doctorates earned are removed from the output variable. However, it is remarkable that roughly 75 percent of these doctoral degrees are in education alone (12,305). Netting out the disproportionate impact of education doctorates reveals the more encouraging fact that Q_i captures and weights 85 percent of all non-education doctorates earned by the baccalaureate alumni on our sample.[19] Thus, on balance, we are comfortable with the ability of Q_i to utilize the JLC data to impart the qualitative differentiation of alumni doctoral achievement which is desired.

3.2 The Sample of Schools

The sample of schools for this study has been increased to 361 institutions, roughly twice the number in the original study. Beyond the obvious advantage of reduced sampling error, this larger sample works to correct for a sampling bias that may have existed before. The original source of baccalaureate school rankings by Ph.D. alumni was limited to the top 200 private institutions. As such, the prior estimation of the model attempted to glean qualitative differences between schools which, by virtue of being among the top 200 baccalaureate producers of Ph.D.s, were qualitatively

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quality of, say, the graduate History, Psychology and Chemistry faculties would necessarily reflect the scholarly stature of the Education or Business program.

[19]Total Doctoral Degrees (52,327) less Education Degrees (12,305) yields Non-Education Degrees (40,022). The sum of Q_i includes 33,917 rated degrees out of a maximum of 40,022 non-education degrees.

similar, at least in a broad sense. The expanded sample offers greater variance in the output measure and thus a stronger test of the generality of our simultaneous model of educational production.

The current sample maintains the focus on private, primarily undergraduate institutions. Specifically, 80 schools lie in category IIA (Comprehensive Institutions) and 281 in category IIB (General Baccalaureate Institutions) as defined in Academe and by the National Center for Education Statistics.[20] This sample character is important since, in the absence of an explicit administrative objective function, the model implies an administrative utility function with arguments, or at least a rank of arguments, which may not be characteristic of university objective functions.[21]

3.3 Variable Construction

Table 3 presents a detailed description of the variables and summarizes the predicted partial relationships developed in Section 2. In order to adjust for differences in school size most observations are expressed in per student-capita terms. Note, however, that the student bases applied in the

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[20]Comprehensive Institutions are defined as having "diverse post-baccalaureate programs, but not engaged in significant doctoral level education ... institutions in which the number of doctoral degrees is fewer than thirty or in which fewer than three doctoral-level programs are offered." General Baccalaureate Institutions have "primary emphasis on general undergraduate education ... institutions in which the number of post-baccalaureate degrees granted in less than thirty or in which fewer than three post-baccalaureate-level programs are offered." (*Academe*, 1983, p. 20).

[21]The reference here is to the difference in emphasis on research and publication at major universities in relation to the administrative and faculty utility functions. The impact which a differently oriented sample of institutions would have for the structural specification of our model are evident from Garvin's (1980) extensive theoretical and empirical treatment of university behavior. See especially Chapters 3, 5, and 6.

per capita calculations are not uniform across variables. The per capita adjustment of the output variable (Q) is based on the number of actual full-time undergraduate students, as opposed to "full-time undergraduate-equivalent students" (FUE) in the case of input variables. The latter concept weights full-time, part-time, and graduate students differently. The appropriateness of this distinction follows from the fact that the output variable is couched in terms of graduate school achievement. By definition, only undergraduate alumni are included in this measure; and by inference, part-time undergraduates are much less likely to pursue a doctorate. Consequently, a school with a high proportion of graduate and/or part-time students would have its output measure unduly deflated by using FUE, rather than actual full-time undergraduates. In contrast, from an input standpoint, graduate students utilize school resources more intensively than do undergraduates, and full-time students more so than part-time students. Thus, FUE is the appropriate base for assessing input intensities.

Several variables in the model are adjusted for regional cost-of-living differences. This adjustment employs MSA-level (Metropolitan Statistical Area) price indices constructed by Fournier and Rasmussen (1986). A school was assigned a specific MSA price index if it could be placed within that MSA according to the Census Bureau's definitions. Otherwise, the school was assigned a "rest-of-state" price index similarly generated by the Fournier and Rasmussen algorithm.[22]

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[22]Although we received the actual, unpublished indices from Fournier and Rasmussen (F&R), their methodology merits a brief summary. F&R built upon price indices calculated by the Bureau of Labor Statistics Family Budget Series for 37 Standard Metropolitan Statistical Areas in 1970, and 22 of those 37 in 1980. In a regression analysis, they found that several MSA-specific variables explained nearly all of the variation in cost of living

Cost-of-living adjustment to the faculty compensation variable is particularly crucial considering the structure of the model. Because we rely on compensation to reflect differences in faculty quality, it is vital that this variable be purged of purely nominal, non-quality differences in compensation. Cost-of-living adjustment was applied selectively across the remaining variables. Our judgement was guided by whether the value of a dollar-denominated outlay is generally subject to local or national market conditions. For example, expenditures on academic, research, and administrative support and the value of the capital stock are deflated because the purchasing power of these outlays is deemed to be more closely associated with local cost-of-living. The rationale for adjusting these categories seems especially convincing when one recognizes that a substantial portion of these expenses are tied to local wage and real estate costs. This link seems quite direct for academic and administrative support costs (e.g., secretarial and maintenance staff), and at least indirect in influencing the value of the capital stock since construction costs are significantly driven by local wages as well. Still, one can hardly contend that cost-of-living

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(COL), obtaining an adjusted R^2 of 0.9934. Therefore, a specific MSA's 1980 COL is estimated by multiplying the regression coefficients times the MSA-specific attributes. Formally, a COL is estimated as:

$$\begin{aligned} COL = {} & 12{,}810.53 - 36.75 \ln(POP) + 1165.08 \ln(\text{Median Housing Value in \$}) \\ & + (-5{,}276.92 + 1{,}172.99 \ln[\text{Median Housing Value}]) (\text{Northeast Binary}) \\ & + (-1{,}071.06 + 310.60 \ln[\text{Median Housing Value}]) (\text{North-Central Binary}) \\ & + (2{,}534.13 - 519.58 \ln[\text{Median Housing Value}]) (\text{South Binary}) \\ & + 1.63 (\text{Per Capita State Government Revenues}) \\ & + 3.03 (\text{Per Capita Local Government Revenues}) \end{aligned}$$

Since we are only interested in relative living costs, the F&R COL values has been standardized relative to the U.S. population-weighted average COL ($22,595 in 1980 dollars). The resulting COL index has a mean of 0.991 with a standard deviation of 0.066.

Table 3: Variables within the Model

Variable	Mean & Std.Dev.	Min Max	$\frac{\partial Q}{\partial X}$	$\frac{\partial S}{\partial X}$	$\frac{\partial F}{\partial X}$	Definition and Comment
Output (Q)	15.68 15.05	0.58 90.06		+	+	Alumni Career achievement: sum of Ph.D., M.D. & J.D. alumni as described below.
Ph.D.	6.37 7.26	0.00 54.62				Quality-weighted number of alumni Ph.D. recipients in Jones-Lindzey-Coggeshall-ranked fields from 1971-1980[a] per 100 1981 full-time undergraduates.[b]
M.D.	3.62 3.84	0.08 20.70				Twice the number of alumni M.D. degrees from 1978 - 1982[c] (to reflect a ten-year period) per 100 1981 full-time undergraduates.
J.D.	5.69 6.16	0.00 46.53				Number of alumni J.D. degrees from 1968-1977[d] per 100 1981 full-time undergraduates.
Students (S)	1122.91 106.93	720.00 1500.00	+		+	Third-quartile composite SAT score of 1981 freshmen class.[b]
Faculty (F)	22.45 2.91	14.36 31.11	+	+		Mean salary of associate professors in $1,000,[e] adjusted for local cost-of-living differences.[f] Average of 1981-82 and 1982-83 academic years.
Capital (K)	13.19 5.37	4.11 32.40	+	+	?	1981 book value of the capital stock,[g] adjusted for local cost-of-living differences, per student-capita[h] in $1,000.
Academic (AC)	0.42 0.28	0.05 2.33	+	+	?	1981 academic support outlays,[g] adjusted for local cost-of-living differences, per student-capita in $1,000. On average, 54 percent of these outlays reflect library expenditures.
Administrative (AD)	1.62 0.72	0.15 8.84	+			1981 administrative support outlays,[g] adjusted for local cost-of-living differences, per student-capita in $1,000.
Research (RE)	1.32 4.39	0.00 52.85	?		?	1981 research support outlays from any source,[g] adjusted for local cost-of-living differences, per faculty-capita in $1,000.
Tuition (T)	4.68 1.32	0.12 8.37		?		1981 tuition[b] in $1,000.
Scholarships (SCH)	40.14 27.39	7.01 326.85		?		1981 scholarship expenditure,[g] as a percentage of tuition, per scholarship recipient. Excludes scholarships like ROTC, where the school is not allowed to select the recipient.
% on Scholarship (%SCH)	44.80 13.92	14.00 81.00		?		Estimated percentage of undergraduates receiving grants from any source in 1981-82 academic year.[b]
Endowment (E)	18.58 15.33	3.90 112.43			+	1981 endowment[g] per student-capita in $1,000.
Faculty/Student Ratio (FSR)	5.54 1.41	2.67 11.56	+	+	?	1981 full-time faculty[e] per 100 student-capita.
Instructor/ Student Ratio (ISR)	0.59 0.47	0.00 3.25	+	+	-	1981 full-time instructors[e] per 100 student-capita.
Undergraduate Specialization Ratio (USR)	80.56 16.95	29.56 100.00	+	+	-	Undergraduate specialization ratio calculated as the number of full-time undergraduates per 100 students.[b]

(continued)

Table 3: Variables within the Model (Continued)

Variable	Mean & Std.Dev.	Min Max	∂Q/∂X	∂S/∂X	∂F/∂X	Definition and Comment
Campus Index #1 (NE Prep)	10.00 1.00	7.97 13.15		?		Campus life factor index of sports and performing arts reminiscent of a New England Prep school.
Campus Index #2 (Joe College)	10.00 1.00	6.01 12.31		?		Campus life factor index of sports and performing arts depicting a traditional college atmosphere.
Campus Index #3 (Artsy)	10.00 1.00	7.58 12.58		?		Campus life factor index of sports and performing arts dominated by the arts.
Campus Index #4 (California)	10.00 1.00	7.45 12.24		?		Campus life factor index of sports and performing arts weakly portraying the California stereotype.
Curricular Index #1 (Flexible)	10.00 1.00	5.56 11.23	?	+		Curricular factor index describing a flexible academic program.
Curricular Index #2 (Depth)	10.00 1.00	6.74 12.08	?	+		Curricular factor index indicating a focus on intensive academic programs.
Curricular Index #3 (Local)	10.00 1.00	8.14 12.28	?	+		Curricular factor index portraying a college cooperating with the local community.
Curricular Index #4 (Academic)	10.00 1.00	7.18 11.82	?	+		Curricular factor index concentrating on traditional academic programs.
% Male Students (%MSTUD)	44.05 18.80	0.00 100.00	+	?		Full-time male population per 100 full-time undergraduates.[b]
% Male Associate Professors (%MFAC)	75.53 17.21	0.00 100.00			+	Percentage of associate professors who are male.[e]
% Tenured Senior Faculty (%TEN)	82.20 19.84	0.00 100.00			+	Percentage of associate and full professors who are tenured.[e]
% Business Majors (%BUS)	19.27 13.25	0.00 77.00	-		+	Percentage of undergraduates who are business majors.[b]
% Engineer Majors (%ENG)	1.66 6.10	0.00 64.00	-		+	Percentage of undergraduates who are engineering majors.[b]
% Education Majors (%ED)	8.96 9.33	0.00 50.00	-		-	Percentage of undergraduates who are education majors.[b]

[a] Source: National Research Council (1986).

[b] Source: The College Board (1981, 1982, 1986).

[c] Source: Academy of American Medical Colleges, Washington, D.C.

[d] Source: American Bar Foundation, Chicago, Illinois.

[e] Source: AAUP (1982, 1983). These figures have been averaged over 2 academic years to partially correct for the undue influence in small faculties of the promotion of faculty members into or out of the associate level.

[f] Source: Fournier and Rasmussen (1986) have generously provided us with their unpublished cost-of-living estimates for all U.S. Metropolitan Statistical Areas (MSA) as well as for each state's non-metropolitan area.

[g] Source: United States Department of Education (1982).

h Undergraduate equivalent population reflects the conversion of full and part-time undergraduate and graduate students to a full-time undergraduate student equivalent (FUE). These sub-populations are weighted according to: FUE = [(#FU x 1) + (#PU / 3) + (#FG x 1.25) + (#PG / 3)]; where #FU is a number of full-time undergraduates, #PU is number of part-time undergraduates, #FG is number of full-time graduates, and #PG is number of part-time graduates. This full-time equivalent number is used in computing all variables denoted as "per student-capita."

adjustment can be cleanly applied to all expenses within a given category. For instance, academic expenditure encompasses library acquisitions, the prices of which probably reflect a national publishing market. At the same time, the academic support line item also includes outlays for library and other non-faculty staff, expenses which are dominated by local wages. Further, the capital stock represents a particularly tough call for a variety of reasons. Even though our general criterion leads us to deflate this variable due to local differences in labor cost, the cost of heavy equipment and construction materials might be less locally driven, and perhaps especially so in the case of major capital projects. Moreover, even if significant local cost differences do exist in the capital expenditure area, deflation by a local producer price index, were one available, would be preferable. Finally, the analytical benefit attained by adjusting the capital stock for local cost-of-living may be relatively modest compared to another problem -- the capital stock datum reflects the book value of the school's plant. This fact introduces substantial difficulty in comparing the real capital stock for two schools of markedly different vintage.

Tuition and endowment are two variables left in nominal terms. In the case of tuition, this seems appropriate because the relative price comparisons by prospective students and their parents are comparisons of nominal tuition costs vis-a-vis their nominal income, irrespective of the region where the income is earned. In other words, the choice set of schools open to students is not limited to their local or regional schools, and therefore nominal differences in tuition should be retained across regions. Regarding the endowment, this variable is left in nominal terms because it is used in the model as a measure of a earnings potential, the source of which is investment in national financial markets. It would be inappropriate to adjust the value of the endowment itself for local cost-of-living because this would in turn alter its earnings stream, which is unrelated to local conditions. Of course, once the purchasing power of the endowment manifests itself as expenditure, it is cost-of-living adjusted; but this does not warrant altering the endowment base upon which the earnings accrue.

Another set of variables from Table 3 merit special attention. Recall from Section 2 that indexes of campus life ($Campus_{1-4}$) and special curricular offerings ($CURR_{1-4}$) are included in the model. All eight of the indexes are placed in the student equation reflecting the assumption that students' choices are influenced by the academic as well as social breadth of an institution. Given the academic orientation of the output variable, only the curricular indexes are included in the output equation.

The indexes have been obtained by exploratory factor analysis.[23] Tables 4 and 5 provide a descriptive overview of the variables used to construct the campus life and academic indexes, respectively. The tables list the specific institutional program, that program's correlation with the factor index, and the proportion of the sample schools offering the program. For clarity, only programs with a correlation of at least 0.30 with the factor index are included in the table. In the case of the campus life

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[23]Technically, a principal components factor analysis was employed with varimax orthogonal rotation. We allowed the procedure to continue extracting common factors for the curricular indexes until the eigen value for the last factor fell below 1.0. While sixteen campus life indexes were extracted using this criterion, the latter factors had little intuitive appeal. Experimentation with additional campus life indexes indicated that they added very little to the model.

indexes, Table 4 also notes that these attributes fall generally between the two broad categories of sports (S) and performing arts (A).

Although intuitive interpretations of factor indexes are seldom pure, inspection of the contents of each index does suggest some meaningful qualitative distinctions. The clearest examples lie in the campus life indexes. First observe how Indexes #1 & #2 are generally sports dominated, as compared with the performing arts orientation of Index #3, "Artsy". Even within the sports domain in general, however, there is a rather intriguing difference in the socioeconomic orientation of students likely to be attracted by the respective sports menus. Considering the list of sports for Index #1 --lacrosse, ice hockey, fencing, sailing -- the image of the affluent "New England Prep" is difficult to suppress. In contrast, Index #2 connotes a more traditional sports core, one more closely associated with "Joe College". And while we might be stretching the point, Index #4 is reminiscent of the "California" stereotype with squash, water polo, diving, and choreographed ensembles. Overall, the character of the indicators included within the respective Campus life indexes suggests that traceable differences exist across institutions in terms of campus life, and thus it is desirable to capture these when modeling student choice. We shall not, however, hypothesize regarding the signs of the relationships between such institutional differences and student quality as measured by SAT score.

Compared to the campus life indexes, the curricular indexes are considerably less tidy from the standpoint of intuitive interpretation. This may arise from the fact that the factor analysis is not operating with the same potential diversity within curricular programs across schools as exists in sports and performing arts. Nevertheless, Index #1 seems to reflect

Table 4: Correlations Between Campus Life Indices and their Observed Indicator Variables

Factor Index # 1: NE Prep

Dichotomous Variable	Corr. with Index	Sample Prop.
S: Lacrosse	0.74	0.28
S: Rugby	0.67	0.22
S: Ice Hockey	0.59	0.25
S: Swimming	0.59	0.18
S: Field Hockey	0.51	0.42
S: Fencing	0.48	0.24
S: Sailing	0.48	0.19
A: Dance	0.46	0.51
S: Skiing	0.42	0.35
S: Horseback Riding	0.35	0.15
S: Water Polo	0.33	0.22
S: Paddleball	0.31	0.17

Factor Index # 2: Joe College

Dichotomous Variable	Corr. with Index	Sample Prop.
S: Baseball	0.68	0.79
S: Football	0.68	0.80
Greek System	0.63	0.58
S: Golf	0.63	0.82
S: Wrestling	0.48	0.44
S: Bowling	0.40	0.56
A: Pop Band	0.38	0.46
S: Softball	0.32	0.96
S: Track	0.30	0.67

Factor Index # 3: Artsy

Dichotomous Variable	Corr. with Index	Sample Prop.
A: Concert Band	0.75	0.58
A: Jazz Band	0.67	0.55
A: Marching Band	0.58	0.16
A: Symphony Orch.	0.55	0.47
A: Music Ensembles	0.52	0.72
A: Opera	0.46	0.21
S: Track	0.46	0.67
A: Pop Band	0.32	0.46

Factor Index # 4: California

Dichotomous Variable	Corr. with Index	Sample Prop.
S: Squash	0.72	0.66
S: Diving	0.71	0.34
S: Water Polo	0.57	0.22
A: Music Ensembles	0.39	0.72

The following indicators had correlations less than 0.30 with each of the factor indexes. The proportion of schools offering the activity is noted parenthetically. Communications and Publications: paper (0.99), magazine (0.69), yearbook (0.97), radio (0.69), TV (0.23), and film (0.20). Performing Arts: choral (0.98), drama (0.98), and theater (0.69). Sports: archery (0.24), badminton (0.43), basketball (0.99), boxing (0.04), cross-country (0.74), gymnastics (0.26), handball (0.38), racquetball (0.46), rifle (0.14), rowing (0.12), skin diving (0.07), soccer (0.82), table tennis (0.42), tennis (0.99), and volleyball (0.99).

Table 5: Correlations Between Curricular Indices and their Observed Indicator Variables

Factor Index # 1: Flexible

Dichotomous Variable	Corr. with Index	Sample Prop.
Internships	0.74	0.90
Independent Study	0.68	0.94
Student-Designed Major	0.60	0.68
Double Major	0.36	0.86

Factor Index # 2: Depth

Dichotomous Variable	Corr. with Index	Sample Prop.
3-2 Lib. Arts & Career	0.67	0.63
Study Abroad	0.65	0.86
Honors Program	0.43	0.60
Other	0.41	0.42
Double Major	0.36	0.86

Factor Index # 3: Local

Dichotomous Variable	Corr. with Index	Sample Prop.
Cooperative Education	0.75	0.27
Honors Program	0.54	0.60
Cross-Registration	0.53	0.57

Factor Index # 4: Academic

Dichotomous Variable	Corr. with Index	Sample Prop.
Accelerated Program	0.68	0.56
Other	-0.54	0.42
Double Major	0.46	0.86

curricular "Flexibility" by virtue of internships, independent study, and student-designed majors. Index #2 captures a slightly different dimension of curricular "Depth" in the form of the five-year arts & career, study abroad, and honors programs. The images implied by Indexes #3 and #4 are less focused, however. Index #3 has been labeled "Local" because of the availability of cooperative education (alternating full-time periods of study and work) and cross-registration with other universities, but the strength of an honors program in this index muddies the water. Finally, one might interpret Index #4 as traditionally "Academic" because of the availability of accelerated programs and double majors, as well as the negative correlation with "other programs".

Regarding the predicted signs on the curricular indexes, one would expect generally positive relationships in the student equation. The signs in the output equation are indeterminate, however. Again, this ambiguity can be traced to the emphasis on graduate training in the output variable. For example, consider how the specific programs contained in Indexes #1 and #2 are likely to have mixed impacts from the standpoint of fostering graduate study. Note that these indexes contain programs of a career orientation directly following the baccalaureate degree (internships, 3-2 Liberal Arts & Career) as well as programs more inclined to stimulate a student toward graduate school (e.g. independent study, honors program). Given the nature of our output measure, the efficacy of career-oriented programs at the undergraduate level would tend to depress production, while curricular offerings such as an honor program would probably contribute.

4. Empirical Results

Discussion of the results is developed on two levels. First, the results of the expanded model are interpreted, giving particular emphasis to the relative productivity of the significant inputs. These results are also compared with the findings of our earlier study. Second, two sets of comparative estimations are performed with the expanded model. These comparisons are presented to demonstrate the sensitivity of the parameter estimates to: 1) quality adjustment of the output variable, and 2) local cost-of-living adjustment of expenditure variables.

4.1 Empirical Results and Policy Implications

The results of the three-stage least-squares estimation appear in the first column of Table 6. Inspection of the output equation (Q) confirms the strong quantitative and statistical significance of faculty quality, academic expenditure, and faculty-student ratio. Student quality is also revealed to be important, although it is somewhat surprising that this variable is of only border line significance. Perhaps the most conspicuous non-result is the apparent insignificance of capital in the output equation. In part, this result may flow from the problems of capital stock valuation noted earlier. Also, it turns out that the performance of the capital stock variable is quite sensitive to local cost-of-living adjustment, as shall be revealed in the next section. Generally, the curricular indexes suggest that differences in program offerings are relatively inconsequential. Only $CURR_3$ is significant, and weakly so at that. Finally, note the consistent performance of the control variables in the output equation. As hypothesized, relatively high proportions of undergraduate business or engineering majors reduce an institution's production of Ph.D./M.D./J.D. alumni for reasons unrelated to institutional quality.

Thus, overall, the parameters in the output equation suggest a rather plausible, indeed traditional, recipe for undergraduate education -- a relatively high ratio of quality faculty to good students in a facilitating environment reflected by academic expenditure. A numerical example is useful in demonstrating the relative efficacy of additional expenditure on these statistically significant inputs. For illustration, consider a school of 1,000 full-time undergraduates which has the average faculty-student ratio (55 faculty members) and pays the average faculty compensation ($26,740) for the schools in the sample. Further assume an institutional objective to raise output by 10 doctoral degrees per 100 students. Based on the parameter estimates, this policy would require increasing academic expenditure by $1.6 million, all other inputs held constant.[24] This same outcome could also be achieved by altering the faculty-student ratio. Holding faculty quality constant (i.e. continuing to pay the average faculty compensation), this strategy would mean doubling faculty size from 55 to 109, with an implied cost of $1.45 million. A third alternative would be to raise faculty quality, holding faculty size constant, at a cost of $0.28 million. Note that of the three options, improving faculty quality is the

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[24]For example, this result is obtained as follows. The 6.21 coefficient implies that a $1,000 per student increase in academic expenditure will result in a long-run (10 years) increase of 6.21 doctoral degrees per 100 enrolled students. For a school size of 1,000 the $1,000 per student increase translates into a $1 million expenditure. Finally, to raise the level by 10 instead of 6.21 the required increase is $1 million x (10/6.21), or $1.6 million.

Table 6: Results of Three-Stage Least-Squares Estimation

	Coefficients & (t-values)			Elasticities at the Sample Means*					
	Current Study: Q = PhDs + MDs + JDs; n=361			Current Study: Q = PhDs + MDs + JDs; n=361			Earlier Study: Q = PhDs; n=174		
	Q	S	F	Q	S	F	Q	S	F
Output (Q)		2.31‡ (2.72)	0.06† (1.74)		0.03‡	0.04†		-0.04	0.01
Students (S)	0.04† (1.80)		0.02‡ (3.86)	2.86†		0.67‡	-1.76		0.89‡
Faculty (F)	1.95‡ (3.84)	12.55‡ (3.85)		3.23‡	0.30‡		2.46†	0.50‡	
Capital (K)	0.15 (1.02)	1.83† (1.69)	-0.11† (2.42)	0.12	0.02†	-0.05†	0.10	0.03†	-0.07‡
Academic (AC)	6.51‡ (3.03)	-18.60 (1.06)	0.09 (0.13)	0.17‡	-0.01	0.00	0.16‡	0.02†	-0.01
Administration (AD)	0.47 (0.67)			0.05			0.53‡		
Research (RE)	-0.14 (1.14)		0.07† (2.28)	-0.01		0.00†			0.00
Tuition (T)		13.10‡ (3.22)			0.05‡			0.14‡	
Scholarships (SCH)		-0.30‡ (2.76)			-0.01‡			-0.03‡	
% on Scholarship (%SCH)		-0.11 (0.50)			-0.00				
Loans (L)								-0.00	
Endowment (E)			0.06‡ (3.13)			0.04‡			0.05‡
Faculty/Stud. Ratio (FSR)	1.91‡ (3.54)	-4.72 (1.05)	-0.25 (1.56)	0.66‡	-0.02	-0.05	1.00‡	0.13‡	-0.14‡
Instrct./Stud. Ratio (ISR)	1.69 (1.34)	0.35 (0.04)	-0.65† (1.80)	0.06	0.00	-0.01†			
Undergraduate Spec. (USR)	-0.03 (0.81)	-0.25 (0.93)	0.00 (0.27)	-0.15	-0.02	0.01	1.21‡	0.15‡	-0.15‡
Campus #1 (NE Prep)		-0.04 (0.01)			-0.00				
Campus #2 (Joe College)		-0.09 (0.03)			-0.00				
Campus #3 (Artsy)		3.72 (1.24)			0.03				
Campus #4 (California)		-2.81 (0.94)			-0.02				
Curricular #1 (Flexible)	-0.58 (0.81)	8.01† (2.25)		-0.36	0.07†				
Curricular #2 (Depth)	-0.48 (0.77)	7.26† (1.97)		-0.30	0.06†				

(continued)

Table 6: Results of Three-Stage Least-Squares Estimation (Continued)

	Coefficients & (t-values)			Elasticities at the Sample Means*					
	Current Study: Q = PhDs + MDs + JDs; n=361			Current Study: Q = PhDs + MDs + JDs; n=361			Earlier Study: Q = PhDs; n=174		
	Q	S	F	Q	S	F	Q	S	F
Curricular #3	1.02†	-3.46		0.63†	-0.03				
(Local)	(2.08)	(1.10)							
Curricular #4	-0.81	4.09		-0.50	0.04				
(Academic)	(1.66)	(1.30)							
% Male Stud's	0.16‡	-0.22		0.43‡	-0.00		0.26†	0.04‡	
(%MSTUD)	(4.62)	(0.71)							
% Male Assoc.			0.02†			0.05†			
Fac. (%MFAC)			(1.88)						
% Tenured Sen.			0.01			0.02			
Fac. (%TEN)			(1.58)						
% Business	-0.21‡		0.02†	-0.25‡		0.02†			
Maj's (%BUS)	(3.61)		(1.75)						
% Engineering	-0.29‡		0.06‡	-0.03‡		0.00‡			
Maj's (%ENG)	(3.36)		(2.76)						
% Education	-0.02		-0.03†	-0.01		-0.01†			
Maj's (%ED)	(0.31)		(1.81)						
North Atlantic (NA)									0.01†
Great Lakes (GL)									0.01†
Western (W)									0.00†
Constant	-90.11‡	578.50‡	6.94						
	(6.71)	(5.20)	(1.50)						
Mean	16.12	1122.91	26.74	16.12	1122.91	26.74	11.84	1040.74	23.45
Std Dev.	15.50	106.93	3.81	15.50	106.93	3.81	8.01	109.48	2.62
Std Error	10.00	72.54	2.84	10.00	72.54	2.84	5.20	68.28	1.93
2S ResCor	1.00			1.00			1.00		
	-0.34	1.00		-0.34	1.00		0.43	1.00	
	-0.32	-0.60	1.00	-0.32	-0.60	1.00	-0.44	-0.80	1.00
3S ResCor	1.00			1.00					
	0.23	1.00		0.23	1.00				
	-0.14	0.17	1.00	-0.14	0.17	1.00			

* Beyond extending the sample and revising the model, a number of definitional changes have been made between the earlier and current studies. Q now includes M.D.'s and J.D.'s as well as Ph.D.'s; Q adjusts Ph.D.'s for quality of the graduate program; and Q excludes Ph.D.'s obtained in non-ranked fields. Furthermore, the denominator for Q is now full-time undergraduates rather than full-time undergraduate equivalents. S is now third-quartile instead of median SAT. F now includes pecuniary fringe benefits as well as salary. F, K, AC, AD, and RE have been adjusted for geographic cost-of-living differences. Consequently, regional binaries (NE, GL, W) are no longer used. SCH is now measured in terms of percentage of tuition for each scholarship recipient rather than $1,000 per student-capita. The denominator for USR has been changed from full-time undergraduate equivalents to total number of students.

† Denotes significance at the 0.05 level

‡ Denotes significance at the 0.01 level

most cost-effective choice by a substantial margin. However, the policy implication of this finding should not be misconstrued. It does not mean that increases in compensation across an existing faculty is the most efficient means to enhance institutional output. Rather, this result means that it is most cost-effective in the long run to raise compensation in order to attract better faculty, and equivalently, to retain quality faculty who would move without higher compensation. The policy significance of the latter point is perhaps especially pertinent if quality faculty are considering leaving academe altogether, rather than moving between institutions.

Technically, of course, the calculations performed in the above example are implicitly *ceteris paribus* estimates, and thus do not capture the endogenous effects of changing the level of any significant input. For example, examine the parameters in the student equation. Observe that raising faculty quality is also predicted to raise student quality, which in turn has separate positive output effects. In other words, the *ceteris paribus* examples are effective in assessing relative factor impacts, but in an absolute sense, the examples slightly overstate the estimated cost due to endogenous impacts which are ignored.

The fact that endogeneity is an important dimension when modeling the educational process is amply demonstrated by the significance of all three endogenous variables across the output, student and faculty equations. Furthermore, the results confirm the cross-equation correlation of error as a source of bias in OLS estimates. The last two items in Table 6 present error correlation matrices following the second and third-stage estimations. Observe that while relatively high cross-equation error-correlation is apparent in the second stage, the magnitude of the correlation is substantial reduced in the third stage, especially between the faculty and student equations where it is most serious.

Although they are of secondary importance to the output equation, the student and faculty equations each invite some interesting interpretations. The parameters for the student quality equation indicate that better students are drawn to schools by output, the capital plant, faculty quality, and curricular flexibility ($CURR_1$) and depth ($CURR_2$). As in output equation, faculty quality again shows a large quantitative impact on student quality -- a $1,000 increase in associate professor compensation is estimated to raise third quartile SAT score of the entering class by more than 12 points in the long run. Better students also appear to be influenced by the physical amenities of the campus as measured here by the value of the capital stock, although the capital coefficient is only weakly significant. The campus life indexes are revealed to be uniformly insignificant. A plausible interpretation of this result is simply that quality students are not oriented disproportionately to any particular sports or artistic dimension.

Somewhat striking at first blush is the negative significance of scholarships on student quality. However, as suggested in Section 2, the Ehrenberg and Sherman (1984) finding may be surfacing here as well, albeit in a slightly different context since our sample contains a much broader range of institutional quality.[25] It is conceivable that less highly

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[25]Recall, the Ehrenberg and Sherman study examined the efficacy of Cornell's financial aid strategy relative to a select group of Ivy League competitors.

regarded institutions use the financial lure more extensively, but nevertheless, remain relatively unsuccessful bidders. This logical thread might also extend to account for the seemingly perverse relationship suggested by the positive sign of the tuition coefficient in the student equation. If tuition is perceived as a true index of institutional quality, one would expect to find better students at more expensive schools. Indeed, tuition differences may be capturing qualitative differences which are not explicitly included in the student equation. In essence, the strongly positive influence of tuition on student quality may be symptomatic of omitted variables in this segment of the model. Broader implications of this finding will be developed further in the final section.

Recall from the discussion in Section 2 that the faculty equation in our model was described as a reduced-form equation from a supply-and-demand system for faculty quality. Generally, the results support this interpretation. Observe that, from a supply perspective, institutional output, quality students and the financial security of a school's endowment are all significant factors drawing quality faculty. However, from a factor demand standpoint, the resource trade-off between well-paid faculty and competing inputs is evident from the significant negative coefficients on instructor-student ratio (ISR) and the capital plant. For example, a one percentage point increase in ISR is predicted to cost associate professors $650 in annual compensation. Similarly, the negative and significant sign on capital suggests that the quality of physical facilities serves as a substitute for quality faculty. Also note that the control variables in the faculty equation perform consistently with our theoretical intent. The signs and significance of percent business (+), engineering (+), and education (-) majors suggest that the parameter estimates in the output equation are appropriately adjusted for differences in compensation due to segmented labor markets rather than true faculty quality.

From a general modeling perspective, it is particularly instructive to compare the results of the current model with our earlier study. Since the model has been improved in ways enumerated in the table notes, it is more meaningful to compare elasticities rather than the coefficients themselves. The elasticities from the respective estimations are presented in the second and third columns of Table 6.

Considering that we have broadened our output measure and sharpened the model in many other respects, the robustness of the findings is gratifying, if not remarkable. For example, the importance of faculty quality, academic expenditure, and the faculty/student ratio remain highly significant in the output equations. Moreover, even the elasticities themselves are reasonably consistent across the two estimations. However, the current results are quite superior in an important respect -- one sees considerably stronger evidence of endogeneity between the output, student, and faculty equations. In the current results, the endogenous variables are statistically significant in all six occurrences, in fact, at the one-percent significance level in four cases. Compare these results with the previous study in which the bulk of the endogeneity revolved around faculty quality. Indeed, the generally weak role of student quality was a major surprise in the earlier results.

Conceptually, the enhanced role of student quality throughout the present model seems quite consistent with improvements in the operational definitions of two of the endogenous variables. First, recall that student quality is now measured by third-quartile SAT score rather than median score. Focus on the upper tail of a school's aptitude distribution is appropriate given the relatively high achievement orientation of the career paths represented in the output variable. Second, expanding the breadth of alumni achievement to include M.D.'s and J.D.'s, as well as the quality adjustment of Ph.D.'s, should improve the sensitivity of the output variable to varying student quality. Both of these adjustments are plausible, if not compelling, explanations for the heightened significance of student quality in the model.

The only variable losing significance in the current study is administrative support. While the careful reader might also cite the uniform change in the status of undergraduate specialization ratio, this result in the earlier study was probably largely the result of a misspecification which has been remedied.[26]

4.2 Significance of Ph.D. Quality and Cost-of-Living Adjustments

Section 2 discussed the potential importance within our model of two data refinements. First, the Ph.D. component of the output variable (Q) has been adjusted for quality differences across graduate programs. Because the college output measure is couched in terms of academic quality, weighting Ph.D.'s from superior graduate programs more highly is, in our judgement, an important refinement of Q. The second adjustment attempts to remove geographical cost-of-living differences from faculty compensation and selected

[26] Because per capita adjustment of Q was based on full-time equivalent students rather than actual full-time undergraduates, the significance of the undergraduate specialization ratio was almost tautological.

university expenditures. It is obviously preferable that differential expenditures across universities reflect real disparities rather than mere price differences. The purpose of this section is to evaluate the sensitivity of the results to these two refinements. We consider the Ph.D. quality adjustment and cost-of-living adjustment in turn.

Table 7 presents three sets of three-stage least-squares estimates for the Q, S and F equations. The first set replicates the results from Table 6 as a basis for comparison. The second set utilizes the same model but redefines Q such that the Ph.D. component is not quality adjusted. The third set goes one step further by including Ph.D.'s achieved in fields which previously had to be excluded from Q due to the unavailability of program rankings in the Jones-Lindzey-Coggeshall study. Recall, these fields include agriculture, health sciences, professional fields such as business, and predominantly education. The averages for these alternative Q's are 15.7, 15.6 and 18.6, respectively. The similarity between the first two averages is the intended result of our scaling the quality weighting index to have a unitary mean across the 361 schools in our sample. Consequently, the output measures have comparable interpretations -- the per-student-capita number of doctoral degrees achieved by baccalaureate alumni per decade. The advantage of the first definition over the others is that it measures equal-quality Ph.D. degrees. The twenty percent higher average of the third output measure (All Ph.D.'s) reflects the substantial number of doctorates attained in unranked fields. This comparison alone is perhaps suggestive of the potential importance of distinguishing quality from quantity in identifying the relative productivities of inputs in institutional production.

Table 7: Adjusting Ph.D.'s for Quality Differences in Graduate Programs; Three-Stage Least-Squares Results With and Without Adjustment

	PhD's: With Quality Adj.; Ranked Fields Only — Coefficients & (t-values)			Phd's: No Quality Adj.; Ranked Fields Only — Coefficients & (t-values)			Phd's: No Quality Adj.; All Fields — Coefficients & (t-values)		
	Q	S	F	Q	S	F	Q	S	F
Output (Q)		2.31‡ (2.72)	0.06† (1.74)		2.24† (2.23)	0.07† (1.91)		1.81† (2.02)	0.04 (1.28)
Students (S)	0.04† (1.80)		0.02‡ (3.86)	0.02 (1.05)		0.02‡ (3.95)	0.02 (0.99)		0.02‡ (4.46)
Faculty (F)	1.95‡ (3.84)	12.55‡ (3.85)		1.96‡ (4.36)	13.37‡ (4.06)		1.85‡ (3.73)	13.98‡ (4.36)	
Capital (K)	0.15 (1.02)	1.83† (1.69)	-0.11† (2.42)	0.24† (1.81)	1.83 (1.63)	-0.12† (2.61)	0.23 (1.58)	2.00† (1.79)	-0.12‡ (2.64)
Academic (AC)	6.51‡ (3.03)	-18.60 (1.06)	0.09 (0.13)	4.92‡ (2.55)	-13.73 (0.79)	0.15 (0.22)	5.80‡ (2.75)	-13.20 (0.74)	0.27 (0.41)
Administration (AD)	0.47 (0.67)			0.23 (0.35)			0.62 (0.83)		
Research (RE)	-0.14 (1.14)		0.07† (2.28)	-0.13 (1.18)		0.07† (2.28)	-0.09 (0.71)		0.07† (2.25)
Tuition (T)		13.10‡ (3.22)			14.37‡ (3.48)			14.70‡ (3.55)	
Scholarships (SCH)		-0.30‡ (2.76)			-0.33‡ (2.90)			-0.33‡ (2.90)	
% on Scholarship (%SCH)		-0.11 (0.50)			-0.10 (0.45)			-0.15 (0.66)	
Endowment (E)			0.06‡ (3.13)			0.06‡ (3.33)			0.07‡ (3.63)
Faculty/Stud. Ratio (FSR)	1.91‡ (3.54)	-4.72 (1.05)	-0.25 (1.56)	1.69‡ (3.48)	-4.04 (0.89)	-0.25 (1.55)	1.90‡ (3.60)	-3.62 (0.79)	-0.24 (1.47)
Instrct./Stud. Ratio (ISR)	1.69 (1.34)	0.35 (0.04)	-0.65† (1.80)	1.50 (1.32)	0.77 (0.08)	-0.64† (1.77)	1.72 (1.39)	0.80 (0.08)	-0.66† (1.82)
Undergraduate Spec. (USR)	-0.03 (0.81)	-0.25 (0.93)	0.00 (0.27)	-0.05 (1.34)	-0.21 (0.78)	0.00 (0.28)	-0.05 (1.44)	-0.24 (0.88)	0.00 (0.23)
Campus #1 (NE Prep)		-0.04 (0.01)			-0.56 (0.12)			0.47 (0.10)	
Campus #2 (Joe College)		-0.09 (0.03)			-0.17 (0.05)			-0.00 (0.00)	
Campus #3 (Artsy)		3.72 (1.24)			3.82 (1.22)			4.87 (1.55)	
Campus #4 (California)		-2.81 (0.94)			-3.44 (1.12)			-2.91 (0.95)	

(continued)

Table 7: Adjusting Ph.D.'s for Quality Differences in Graduate Programs; Three-Stage Least-Squares Results With and Without Adjustment

(Continued)

	PhD's: With Quality Adj.; Ranked Fields Only			Phd's: No Quality Adj.; Ranked Fields Only			Phd's: No Quality Adj.; All Fields		
	Coefficients & (t-values)			Coefficients & (t-values)			Coefficients & (t-values)		
	Q	S	F	Q	S	F	Q	S	F
Curricular #1	-0.58	8.01†		-0.26	7.78†		-0.36	7.22†	
(Flexible)	(0.81)	(2.25)		(0.41)	(2.18)		(0.51)	(2.08)	
Curricular #2	-0.48	7.26†		-0.11	6.48†		-0.14	6.74†	
(Depth)	(0.77)	(1.97)		(0.20)	(1.74)		(0.23)	(1.86)	
Curricular #3	1.02†	-3.46		1.00†	-3.47		1.09†	-3.01	
(Local)	(2.08)	(1.10)		(2.31)	(1.10)		(2.28)	(0.98)	
Curricular #4	-0.81	4.09		-0.73	4.02		-0.69	3.09	
(Academic)	(1.66)	(1.30)		(1.68)	(1.27)		(1.45)	(1.02)	
% Male Stud's	0.16‡	-0.22		0.17‡	-0.24		0.20‡	-0.17	
(%MSTUD)	(4.62)	(0.71)		(5.60)	(0.73)		(5.83)	(0.53)	
% Male Assoc.			0.02†			0.02†			0.02†
Fac. (%MFAC)			(1.88)			(1.86)			(2.18)
% Tenured Sen.			0.01			0.01			0.01†
Fac. (%TEN)			(1.58)			(1.65)			(1.77)
% Business	-0.21‡		0.02†	-0.21‡		0.02	-0.23‡		0.02
Maj's (%BUS)	(3.61)		(1.75)	(3.95)		(1.60)	(3.96)		(1.39)
% Engineering	-0.29‡		0.06‡	-0.28‡		0.06‡	-0.33‡		0.06‡
Maj's (%ENG)	(3.36)		(2.76)	(3.54)		(2.76)	(3.77)		(2.67)
% Education	-0.02		-0.03†	-0.04		-0.03†	-0.03		-0.04†
Maj's (%ED)	(0.31)		(1.81)	(0.62)		(1.70)	(0.42)		(2.17)
Constant	-90.11‡	578.50‡	6.94	-74.43‡	567.92‡	6.99	-71.64‡	527.89‡	5.31
	(6.71)	(5.20)	(1.50)	(6.18)	(4.97)	(1.55)	(5.43)	(4.88)	(1.23)
Mean	16.12	1122.91	26.74	15.58	1122.91	26.74	18.62	1122.91	26.74
Std Dev.	15.50	106.93	3.81	13.99	106.93	3.81	14.79	106.93	3.81
Std Error	10.00	72.54	2.84	9.23	73.31	2.84	9.91	74.04	2.84
2S ResCor	1.00			1.00			1.00		
	-0.34	1.00		-0.27	1.00		0.22	1.00	
	-0.32	-0.60	1.00	-0.36	-0.61	1.00	-0.32	-0.65	1.00
3S ResCor	1.00			1.00			1.00		
	0.23	1.00		0.31	1.00		0.28	1.00	
	-0.14	0.17	1.00	-0.03	0.25	1.00	-0.02	0.16	1.00

† Denotes significance at the 0.05 level

‡ Denotes significance at the 0.01 level

Observe from Table 7 that quality adjustment appears to exert its strongest influence on core variables in the model -- output, student quality, capital, and academic expenditure. Indeed, the role of student quality declines markedly in the output equation when Ph.D.'s are not quality-adjusted. This diminished importance is evidenced by a 50 percent reduction in the coefficient on S (from 0.04 when quality-adjusted to 0.02 without adjustment) as well as by a loss of statistical significance. Academic expenditure, while remaining statistically significant, suffers a 20 percent drop in the coefficient. Considered together these results suggest that certain inputs are especially important in producing quality. It is somewhat surprising, however, that the impact of faculty quality is virtually unaffected by quality adjustment. Note that both the coefficient and t-statistic for F in the Q equation are remarkable stable using either output measure. The changes with respect to faculty quantity (FSR) are negligible as well.[27] Perhaps most surprising, however, are the seemingly perverse changes occuring with respect to the capital stock. When output is not quality adjusted, the capital stock becomes half again as important quantitatively and rises to statistical significance at the 5 percent level. But upon adding unranked fields to output, capital's coefficient then declines slightly and returns to insignificance. Interpretated at face value, this pattern implies that the physical amenities of a campus are more impor-

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[27]While this is true, the last set of results must be qualified since the inclusion of the unranked Ph.D. fields increases Q by about 20 percent on average. If this increase were merely a matter of rescaling, then one might expect the coefficients to rise by about 20 percent vis-a-vis the second set of results. Since, for example, the F coefficient actually declines by about 6 percent, one might infer that faculty quality is noticeably less important in producing Ph.D.'s in the unranked fields.

tant in producing numbers of doctoral-achieving alumni than they are in enhancing the quality of those doctoral degrees.[28]

From the perspective of the input equations, quality adjustment within Q is of only marginal importance in drawing quality students or faculty. The Q coefficients and t-values change only slightly between the first two sets of results. Nor does including unranked Ph.D. fields appear to influence student quality. In fact, observe that the 23 percent decline in the Q coefficients (from 2.24 to 1.81) within the S equation is approximately offset by the 20 percent average increase in Q (from 15.58 to 18.62) between the last two sets of results. The same cannot be said for the faculty equations, however. The Q coefficient drops by a disproportionate 43 percent (from 0.07 to 0.04) and declines to statistical insignificance in the third set of results as well. To the extent that average compensation reflects faculty quality, producing Ph.D. alumni in unranked fields is less of a magnet in attracting quality faculty than Ph.D. production in ranked disciplines, *ceteris paribus*.

The lessons of the adjustment for differential quality among graduate Ph.D. programs can be restated succinctly. The quality of students at a university is much more important in influencing the quality of graduate degrees than it is in affecting their quantity. To a lesser extent, this is also true for academic expenditure. Just the opposite case applies for capital, -- it is apparently more important in producing quantity than

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[28]Actually, the marginal productivity of capital with respect to the quality of the graduate program appears to be negative. We would not press this point, however. Indeed, it is precisely this kind of unstable behavior which leads us to speculate about a broader structure for the model in general. We shall return to this issue in the conclusions.

quality. The quality adjustment plays no substantive role in drawing quality students or faculty, but not all Ph.D. fields attract equal-quality faculty.

Although the preceding lessons are interesting, one might have anticipated more pervasive and dramatic differences resulting from quality adjustment. But in fact, it is quite amazing that differences surfaced at all; the simple correlation between the quality-adjusted and unadjusted numbers of Ph.D.'s turns out to be an astonishing 0.988. This extraordinary correlation is especially surprising in light of the relatively low correlation of 0.518 between the unadjusted numbers of Ph.D.'s and the quality index used for weighting those doctorates. The explanation for this rise in correlation is mechanical. The relatively high variation in Ph.D. numbers (with a standard deviation which is 96 percent of its mean of 6.28) dominates the quality index (with a standard deviation 17 percent of its mean value of unity) when the two are multiplied together. Ex post, the relatively low dispersion within the program-quality rankings is really quite understandable. This result is common in survey instruments using ordinal rankings (0-5 in this particular case). Under such a format, survey respondents have a tendency to render middling ranks in all but the truly extraordinary cases.

Table 8 reveals the significance of geographical cost-of-living (COL) adjustment. Again, three sets of results are presented. The first set replicates the results from Table 6. In this case, faculty compensation (F), the value of the capital plant (K), academic expenditure (AC), administrative expenditure (AD), and research expenditure (RE) are all adjusted

Table 8: Effects of Adjusting $ for Local Cost-of-Living Differences; Three-Stage Least-Squares Results With and Without Adjustment

	Basic Model: COL Adjustments to F, K, AC, AD, RE			No COL Adjustments			COL Adjustments to F, AC, AD, RE		
	Coefficients & (t-values)			Coefficients & (t-values)			Coefficients & (t-values)		
	Q	S	F	Q	S	F	Q	S	F
Output (Q)		2.31‡	0.06†		1.62†	0.02		1.43	0.07†
		(2.72)	(1.74)		(2.00)	(0.43)		(1.55)	(2.04)
Students (S)	0.04†		0.02‡	0.02		0.04‡	0.02		0.02‡
	(1.80)		(3.86)	(0.57)		(7.34)	(0.71)		(4.09)
Faculty (F)	1.95‡	12.55‡		1.72‡	15.03‡		2.41‡	13.64‡	
	(3.84)	(3.85)		(3.77)	(5.38)		(4.94)	(4.22)	
Capital (K)	0.15	1.83†	-0.11†	0.36†	3.00‡	-0.21‡	0.40‡	3.01‡	-0.19‡
	(1.02)	(1.69)	(2.42)	(2.20)	(2.66)	(3.72)	(2.43)	(2.60)	(4.06)
Academic (AC)	6.51‡	-18.60	0.09	7.61‡	-12.77	-0.02	6.05‡	-10.81	0.02
	(3.03)	(1.06)	(0.13)	(3.70)	(0.73)	(0.03)	(2.82)	(0.62)	(0.03)
Administration (AD)	0.47			1.10			0.40		
	(0.67)			(1.57)			(0.56)		
Research (RE)	-0.14		0.07†	-0.04		0.03	-0.16		0.07†
	(1.14)		(2.28)	(0.33)		(0.99)	(1.26)		(2.25)
Tuition (T)		13.10‡			3.94			14.58‡	
		(3.22)			(0.85)			(3.54)	
Scholarship (SCH)		-0.30‡			-0.19†			-0.33‡	
		(2.76)			(2.05)			(3.01)	
% on Scholarship (%SCH)		-0.11			-0.16			-0.11	
		(0.50)			(1.10)			(0.53)	
Endowment (E)			0.06‡			0.05†			0.07‡
			(3.13)			(2.02)			(3.46)
Faculty/Stud. Ratio (FSR)	1.91‡	-4.72	-0.25	1.66‡	-3.10	-0.11	1.60‡	-4.22	-0.18
	(3.54)	(1.05)	(1.56)	(3.25)	(0.71)	(0.57)	(2.97)	(0.96)	(1.11)
Instrct./Stud. Ratio (ISR)	1.69	0.35	-0.65†	0.57	-1.51	-0.15	1.53	-0.48	-0.53
	(1.34)	(0.04)	(1.80)	(0.49)	(0.16)	(0.34)	(1.22)	(0.05)	(1.46)
Undergraduate Spec. (USR)	-0.03	-0.25	0.00	-0.01	0.19	-0.02	-0.04	-0.25	0.00
	(0.81)	(0.93)	(0.27)	(0.13)	(0.68)	(1.22)	(1.14)	(0.95)	(0.35)
Campus #1 (NE Prep)		-0.04			-1.27			-0.22	
		(0.01)			(0.29)			(0.05)	
Campus #2 (Joe College)		-0.09			-0.32			-0.35	
		(0.03)			(0.13)			(0.11)	
Campus #3 (Artsy)		3.72			1.66			3.60	
		(1.24)			(0.81)			(1.20)	
Campus #4 (California)		-2.81			-2.80			-3.62	
		(0.94)			(1.10)			(1.17)	

(continued)

Table 8: Effects of Adjusting $ for Local Cost-of-Living Differences; Three-Stage Least-Squares Results With and Without Adjustment

(Continued)

	Basic Model: COL Adjustments to F, K, AC, AD, RE			No COL Adjustments			COL Adjustments to F, AC, AD, RE		
	Coefficients & (t-values)			Coefficients & (t-values)			Coefficients & (t-values)		
	Q	S	F	Q	S	F	Q	S	F
Curricular #1	-0.58	8.01†		-0.46	5.18†		-0.27	7.60†	
(Flexible)	(0.81)	(2.25)		(0.64)	(1.82)		(0.39)	(2.17)	
Curricular #2	-0.48	7.26†		-0.29	4.22		-0.33	7.22†	
(Depth)	(0.77)	(1.97)		(0.46)	(1.45)		(0.56)	(2.01)	
Curricular #3	1.02†	-3.46		1.00†	-2.17		1.03†	-2.89	
(Local)	(2.08)	(1.10)		(2.09)	(0.88)		(2.19)	(0.94)	
Curricular #4	-0.81	4.09		-0.84	2.79		-0.73	3.46	
(Academic)	(1.66)	(1.30)		(1.75)	(1.14)		(1.57)	(1.13)	
% Male Stud's	0.16‡	-0.22		0.22‡	-0.12		0.17‡	-0.06	
(%MSTUD)	(4.62)	(0.71)		(5.70)	(0.40)		(4.85)	(0.18)	
% Male Assoc.			0.02†			-0.00			0.01
Fac. (%MFAC)			(1.88)			(0.17)			(1.52)
% Tenured Sen.			0.01			0.01			0.01†
Fac. (%TEN)			(1.58)			(1.41)			(1.74)
% Business	-0.21‡		0.02†	-0.25‡		0.02	-0.22‡		0.02
Maj's (%BUS)	(3.61)		(1.75)	(4.17)		(1.56)	(3.85)		(1.43)
% Engineering	-0.29‡		0.06‡	-0.28‡		0.04†	-0.30‡		0.05‡
Maj's (%ENG)	(3.36)		(2.76)	(3.34)		(1.70)	(3.36)		(2.55)
% Education	-0.02		-0.03†	0.02		-0.03†	-0.02		-0.03†
Maj's (%ED)	(0.31)		(1.81)	(0.30)		(1.79)	(0.28)		(1.80)
Constant	-90.11‡	578.50‡	6.94	-65.29‡	593.00‡	-12.88†	-80.60‡	548.83‡	6.15
	(6.71)	(5.20)	(1.50)	(4.30)	(6.60)	(2.27)	(5.83)	(4.91)	(1.31)
Mean	16.12	1122.91	26.74	16.12	1122.91	26.68	16.12	1122.91	26.74
Std Dev.	15.50	106.93	3.81	15.50	106.93	4.18	15.50	106.93	3.81
Std Error	10.00	72.54	2.84	9.41	74.20	3.48	10.47	73.30	2.86
2S ResCor	1.00			1.00			1.00		
	-0.34	1.00		-0.29	1.00		-0.21	1.00	
	-0.32	-0.60	1.00	-0.19	-0.78	1.00	-0.42	-0.62	1.00
3S ResCor	1.00			1.00			1.00		
	0.23	1.00		0.35	1.00		0.36	1.00	
	-0.14	0.17	1.00	0.61	0.36	1.00	0.08	0.35	1.00

† Denotes significance at the 0.05 level

‡ Denotes significance at the 0.01 level

for local COL disparities. The second set makes no COL adjustments, while the third set makes COL adjustments to all but the capital variable.

Generally, the COL adjustment affects the estimates substantively. Even when restricting attention to instances where the level of statistical significance changes, numerous differences can be seen between the COL-adjusted and nominal results. Furthermore, the influences extend beyond the pecuniary variables. Within the output equation, the quantitative and statistical importance of student quality (S) is enhanced by the COL adjustment. In the student equation, output (Q), tuition (T), scholarships (SCH), and the second curricular index are all buttressed as well. Finally, in the faculty equation, output (Q), research expenditure (RE), endowment (E), instructor-to-student ratio (ISR), percentage of associate professors who are male (%MFAC), and percentage of undergraduates majoring in business (%BUS) and engineering (%ENG) all gain though COL adjustment.

There is clearly one discordant note, however, when comparing the first versus second set of results. Observe that Capital (K) is uniformly less influential across all three equations when enumerated in real terms. For this reason, we proceeded with a third estimation in which only capital was expressed in nominal terms. In that form, capital retains its strong level of significance across all three equations. In addition, other variables regain strength initially displayed with COL, but weakened when the model was estimated uniformly in nominal values. This is a vexing anomaly. Conceptually, capital would seem to be one of the more crucial of the pecuniary variables to be COL adjusted. After all, it is dominated by land and construction costs which vary substantially across geographic areas. Furthermore, Fournier and Rasmussen (1986) found median housing value to be the dominant explanatory variable for COL differences across metropolitan statistical areas. On the other hand, our adjustment is based upon consumer COL rather than a preferred, but unavailable, producer price index which would evaluate commercial real estate. As such, perhaps our adjustment is really more appropriate for wage-driven expenditures such as faculty compensation, academic and administrative costs.[29] If commercial real estate values vary less geographically than do housing values, a very large assumption indeed, then the value of capital might be justifiably preserved in nominal terms. For this reason, we include the alternative results in the third column. Another explanation also exists. The volatility of the capital estimates might be attributed to its treatment as an exogenous variable. Plausibly, capital is an important choice variable in an university objective function. As such, its influence might extend to other variables as well.

5. Concluding Remarks and Lines of Future Research

Any reading of the literature in the economics of educational production conveys a clear skepticism for the prospects of meaningful empirical research. Against this backdrop, the conceptual and empirical lessons of this study stand out.

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[29] Complicating all of this is the accounting morass from which the capital figures were obtained. Capital and land are listed at book value rather than market value. While no depreciation enters this accounting, renovations are treated as additions to the capital stock. For schools of widely differing ages and uneven growth rates, a vintage stock model is virtually intractable. Nevertheless, unless relative COL moved perversely to these capital trends, our COL adjustment should not distort the influence of capital.

The strength of simultaneity among quality students, faculty, and institutional output is clearly demonstrated. Further, the results confirm the potential bias of cross-equation error-correlations and thus establish the appropriateness of a three-stage estimation procedure. This study has also introduced an intriguing method of measuring educational production, and has given special emphasis to quality-adjustment within important quantitative variables. Finally, the composite policy recommendation which emerges is, while perhaps unsurprising, worth repeating -- emphasize human capital in the production of human capital. Quality students and quality faculty, buttressed by academic support, are the major cogs driving educational production.

Lest the policy implications of these results seem too one-dimensional, we prefer to stress these findings as a reminder of priorities for educational policy. One could not argue that other factors are not facilitating, only that they contribute less directly to educational production.

On closer inspection, a subtle yet pervasive concept is also discernable throughout the results. This concept addresses the current literature and is also suggestive of further research within the general framework developed here. The empirical relationship revealed in the faculty equation provides an instructive focus in this regard. Recall that we have found universities substitute capital as well as instructional personnel for faculty quality. In other words, administrators of private institutions not only recognize tradeoffs among factor inputs, they react to them. While such a result does not necessarily imply the cost-minimizing strategy of profit-maximizing enterprises, it is certainly inconsistent with Bowen's (1980) view that colleges cost-maximize subject to their ability to raise revenue. Furthermore, this result suggest very strongly that administrative behavior be treated endogenously, just as we have done for students and faculty. In short, faculty and students are important players, but they do not exhaust the cast.

Incorporating a university objective function into our model might clarify anomalies noted previously. For example, recall the strong positive relationship between student quality and tuition. This result is a classic symptom of under-identification in a supply-and-demand relationship. Tuition is a choice variable not only of students, but also of private universities in an imperfect market. Similarly, we question whether the level of the capital stock is not also an important argument within an institution's objective function. For instance, the administrative objective might be to maximize legacies of land, endowment, and capital subject to certain size and/or quality constraints. Furthermore, Garvin (1980) has already provided a useful point of departure for this type of extension, albeit with a predominantly university rather than collegiate orientation.

Despite the obvious conceptual appeal, an administrative equation introduces a host of variables that could arguably be treated endogenously. The faculty-student ratio is a prime example, as is the size of the student body. The problem with this type of broad rethinking of the system is that it ultimately ends with a general-equilibrium treatment of the university environment. While conceptually superior, such a treatment presents a host of theoretical and econometric challenges well beyond the scope of this project. But we believe the conceptual perspective of the current study is the appropriate one, and that the empirical methods applied here extend modestly, yet measurably, in a promising direction.

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