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Introduction

This paper follows an earlier article (Dolan, Jung & Schmidt; 1985) in which we examined the production process of higher education. Two aspects of the original study serve as the basis for this paper and thus warrant brief review.

First, we have argued that educational production does not lend itself to analysis as a production function in the classic sense.[1] A simple production rendering ignores the fact that two of the more important factors, students and faculty, enter the process upon considerable self-selection, especially among the more highly qualified of these inputs. This reasoning led us to model educational production as a three-equation simultaneous system in which the quality of students, faculty, and college output were treated endogenously. The results of that research confirmed the strength of interdependencies existing among the endogenous variables, thus recommending simultaneous estimation as the appropriate methodology for evaluating factors in educational production.[2]

The earlier article also introduced a unique measure of educational output. Production across baccalaureate institutions was measured in terms of the number of alumni who received Ph.D.'s. The usefulness of this type of output measure was noted for its policy implications. Typically, income or achievement test scores have been used as a proxy for educational output. Because these data are specific to individuals and not institutions, previous

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[1]This concept is discussed briefly by Summers and Wolfe (1977, p.639), although it is not the focus of that article.

[2]McGuckin & Winkler (1979, pp. 242-43) make a similar argument for analysis at the intra-university level. 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.

studies have tended to identify factors that affect individual achievement within a single school system or college (Astin, 1968; Bowles, 1970; Summers & Wolfe, 1977; McGuckin & Winkler, 1979). Since institutional characteristics have been held constant, differential aptitude, effort, and social background have dominated the explanation of variability in student achievement. However, variance in these latter factors were arguably less pronounced due to the cross-sectional orientation of our sample to exclusively private, principally undergraduate schools. For this reason, our model related differences in institutional characteristics -- student and faculty quality, and per capita expenditures on various facets of education -- to differences in institutional output. Thus the policy implications, there as well as in this study, are recommendations for enhancing institutional production, not individual achievement.

Largely, the current paper extends the conceptual framework of our earlier work by applying a data set which is enhanced in significant respects. First and foremost, while retaining the concept of alumni career achievement as a measure of college production, this output measure is broadened to include M.D. and J.D. recipients.[3] The school sample has also been increased to 336 institutions, roughly twice the number in the original study. Beyond the obvious advantage of reduced sampling error, this larger sample works to correct a sampling bias which might have existed before. The original source of school rank by Ph.D. alumni was limited to the top 200 private institutions. Thus one might argue that the earlier model was in the situation of attempting to glean qualitative differences between schools which, by virtue of being

[3]For a discussion of the applicability of alumni achievement as a measure of institutional output, see Dolan, et al., p. 514, especially Note 4.

among the top 200 baccalaureate producers of Ph.D.s, were qualitatively similar, at least in a broad sense. The current sample offers greater variance in the output measure and thus an improved empirical base for testing our simultaneous model of educational production. At the same time, the new sample retains its exclusive focus on private, primarily undergraduate institutions. The homogeneity of the sample in this respect is important since the structure of our model implies an administrative utility function with arguments, or at least a rank of arguments, which may not be characterize university objective functions in general.[4] Finally, the current data set is enhanced by additional variables.

Generally, the new results are heartening in the sense that they indicate a degree of robustness in our earlier method. However, this extension has also afforded an element of self-scrutiny which leads us to suggest an important direction for further research in this area.

I. The Model

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

(1) $$Q = f(R,S)$$

where Q, R, and S denote output, resources, and student characteristics. As discussed earlier, a model of higher educational production must reflect

[4]Here, of course, we referring to the difference in emphasis on research and publication at major universities in relation to the administrative and facultly 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.

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 these inputs. To address this interdependence, the relationship expressed in Equation (1) is more appropriately specified by the following three-equation simultaneous system.

(2) $$\Gamma y_i + \beta x_i = u_i$$

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 fourteen exogenous variables, each generally representing institutional characteristics, e.g., tuition, endowment, etc.

Γ = 3x3 matrix of endogenous variable coefficients.

β = 3x14 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 336 private, undergraduate-oriented universities. These are AAUP Category IIA (have diverse post-baccalaureate programs, but do not engage in significant doctoral-level education) and IIB (have diverse baccalaureate-level programs, but do not engage in significant post-baccalaureate education) schools.

Implicitly the model is written:

(3) $$Q = f_Q\ (S, F, K, AC, AD, FSR, USR, \%MSTUD, u_Q)$$

(4) $$S = f_S\ (Q, F, T, K, AC, SCH, L, FSR, USR, \%MSTUD, u_S)$$

(5) $$F = f_F\ (Q, S, E, K, AC, RE, FSR, USR, NA, GL, W, u_F)$$

where Q is the number of alumni Ph.D., M.D and J.D. recipients; S is the third quartile SAT score of the entering freshman class, and F is associate level faculty salary. To adjust for differences in school size, most observations are expressed in per student-capita terms. Details on the listed variables appear in Table 1.

Table 1: Variables Within the Model

Variable (X)	Mean & Std.Dev.	Max Min	$\frac{\partial Q}{\partial X}$	$\frac{\partial S}{\partial X}$	$\frac{\partial F}{\partial X}$	Definition and Comment
Output (Q)	17.60 14.55	81.96 0.72		+	+	Alumni Career achievement: sum of Ph.D., M.D. & J.D. alumni as described below and weighted to reflect 10 year period.
Ph.D	8.64 6.74	48.51 .02				Number of alumni Ph.D. recipients from 1971-1980 per 100 1981 undergraduate equivalent students.[a,b]
M.D.	1.73 1.89	10.05 .03				Number of alumni M.D. degrees from 1978 - 1982 per student-capita.[c]
J.D.	5.39 5.93	34.92 .00				Number of alumni J.D.s from 1968-1977 per student-capita.[d]
Students (S)	1129.35 104.35	1500.00 720.00	+		+	Third quartile composite SAT score of 1981 freshmen class.[e]
Faculty (F)	21.64 2.97	31.10 14.50	+	+		Mean salary of associate professors for 1981-82 in $1,000.[f]
Tuition (T)	4.77 1.31	8.37 .12		?		1981 tuition in $1,000.[e]
Endowment (E)	19.24 15.63	113.02 4.11			+	1981 endowment per student-capita in $1,000.[g]
Capital (K)	13.45 5.33	35.43 3.79	+	+	?	1981 book value of the capital plant per student-capita in $1,000.[g]
Academic (AC)	0.42 0.28	2.31 .04	+	+	?	1981 academic support outlays per student-capita in $1,000. Generally, a substantial part of this value reflects library expenditures.[g]
Research (RE)	1.32 4.43	52.05 .00			?	1981 research support outlays per faculty-capita in $1,000.[g]
Administrative (AD)	1.62 0.71	8.79 0.15	+			1981 Administrative support outlays per student-capita in $1,000.[g]
Scholarships (SCH)	0.76 0.42	2.92 .12		?		1981 scholarship funds per student-capita in $1,000.[g]
Loans (L)	1.09 0.72	7.11 -.08		?		1981 student loan funds per student-capita in $1,000.[g]
Faculty/Student Ratio (FSR)	5.57 1.40	11.62 2.69	+	+	?	1981 Faculty per 100 full-time undergraduate equivalents.
Undergraduate Specialization Ratio (USR)	90.07 11.82	100.00 35.87	+	+	-	Undergraduate specialization ratio calculated as the number of actual full-time undergraduates per 100 full time undergraduate equivalents

(Continued)

Table 1: (Continued)

Variable (X)	Mean & Std.Dev.	Max Min	$\frac{\partial Q}{\partial X}$	$\frac{\partial S}{\partial X}$	$\frac{\partial F}{\partial X}$	Definition and Comment
% Male Students (%MSTUD)	44.17 19.07	100.0 0.0	+	?		Full-time male population per 100 of undergraduate full-time population.
Business Degree (%BUS)	18.76 13.05	53.0 0.0	?		?	Percent undergraduate business majors.[e]
Engineer Degree (%ENG)	1.70 6.23	64.0 0.0	-		?	Percent undergraduate engineering majors.[e]
Education Degree (%ED)	8.68 9.09	50.0 0.0	-		-	Percent undergraduate education majors.[e]
North Atlantic (NA)	0.29 0.45	1.0 0.0			+	Binary variables for geographic regions. These binaries are included to control for salary differentials that could be attributable to regional cost-of-living differences.
Great Lakes (GL)	0.37 0.48	1.0 0.0			+	
Western (W)	0.13 0.33	1.0 0.0			+	

a 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 the following algorithm:

$$FUE = [(\#FU \times 1) + (\#PU \times .25) + (\#FG \times 1.25) + (\#PG \times .5)]$$

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 per student-capita observations

b Source: Baccalaureate Sources of Ph.Ds Rankings According to Institution of Origin National Research Council, Baltimore, Maryland.

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

d Source: American Bar Foundation, Chicago, Illinois.

e Source: Annual Survey of Colleges (New York The College Board Inc., 1982).

f Source: Academe: The Annual Report on the Economic Status of the Profession, 1981-1982, 68 Special Issue (July-Aug. 1982, and July-Aug 1983).

g Source: Higher Education General Information Survey (HEGIS XVI) (Washington, D.C.: United States Department of Education, 1982).

Equation (3) posits that successful Ph.D. candidates are the product of quality human (S, F, AD) and nonhuman (K, AC) resources. Also the nature (USR) and intensity (FSR) of the human element are deemed important in stirring and sustaining post-graduate ambitions. A school's percentage of male students (%MSTUD) is included to adjust for the possibility that M.D.s, J.D.s, and Ph.D.s have been male-dominated degrees.

Equation (4) presents a reduced-form modeling of a somewhat complicated market -- the market for student quality. Viewed as an input, students supply, and universities compete for, the quality necessary to enhance institutional reputations. Considering the output of the educational process, however, students demand and universities supply. Predictions for many of our variables are unaffected by this complication. For example, we argue that quality students are drawn, and institutions vie for them, by reputation as reflected in alumni achievement (Q), faculty quality (F), physical plant (K), academic expenditure (AC), and factors indicating emphasis on the student (FSR & USR). The predicted signs are all positive.

Scholarships and loans (SCH & L) provide mechanisms for an institution to "buy" student quality. While one might expect the financial lure to draw better students, Ehrenberg and Sherman (1984, p. 213) find a relatively low elasticity on the ability of scholarship increases by Cornell to draw the highest quality applicants from schools revealed by students' acceptance decisions to be even more prestigious. Apparently, consumer surplus exists at the preferred schools in excess of the scholarship differential. Were this elasticity low enough among our universities, the linear nature of our system could evince a negative coefficient for SCH and L. Therefore, the predicted sign for these aid variables are left ambiguous. Tuition (T) is another variable which introduces subtleties in 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 our other variables, then T might exert a positive influence. Finally, the proportion of male students (%MSTUD) is included merely as a control for the possibility that males who go on to college have different SAT characteristics than do females. We have no prediction regarding SCH, L, T, and %MSTUD.

Equation (5) employs the average associate professor's salary as our measure of faculty quality. Salary was chosen because of its availability and objectivity of measurement. Furthermore, within the confines of our private, undergraduate-oriented sample of universities, this measure is not appreciably affected by rewards for quality research or by disproportionate salaries for medical and legal faculty. Thus we assume that salary is a university's primary means of attracting and keeping quality faculty in the long run. The associate level was chosen because these faculty are old enough to have established their credentials yet young enough and mobile enough to take advantage of them.[5]

Equation (5) can 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, two variables are included to control for salary differentials unrelated to faculty quality. Colleges with low

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[5]Reestimation of the system using assistant in place of associate professor salaries yielded very similar results. This is not surprising in light of the high correlations between salaries at the various levels -- assistant and associate, 0.873; associate and full, 0.927; and assistant and full, 0.801.

undergraduate specialization ratios (USR) are predicted to have higher average salaries because of the higher salaries paid to graduate professors, especially law professors. Further, we anticipate salaries to be higher in the North Atlantic (NA), Western(W), and Great Lakes (GL) regions vis-a-vis the Southeast because of cost-of-living differences. The remaining variables affect both supply and demand. The size of an institution's endowment (E) represents financial security to faculty and ability-to-pay by institutions, both positive influences. Other variables have offsetting influences resulting in ambiguous predictions for the reduced-form coefficients. While faculty might prefer better physical facilities (K) and higher academic expenditures (AC), institutions might view them as substitutes for faculty. And while faculty might prefer higher research support (RE) and smaller classes (FSR), administration might view these as income-in-kind.

The foregoing discussion applies to the model as cast in our earlier article. For purposes of comparison, we re-estimate this model using the composite career achievement measure and the enlarged sample of schools. We then consider an expanded the model. The additional variables in the expanded model are described at the end of Table 1. Note that the percent of undergraduates majoring in business (%BUS), engineering (%ENG), and education (%ED) are added to the output (Q) and faculty (F) equations. The purpose of these variables is to control for any non-qualitative impact that particular vocational orientations of schools might have on institutional output and faculty quality as defined here. For example, the emphasis of our output measure on graduate degrees might unfairly reflect the production of schools with high percentages of the business, engineering, or education majors since these undergraduate degrees are often terminal. In terms of the faculty equation, such vocational curricula have staffing requirements which might imply salary differentials which should not be interpreted as differences in faculty quality in general. Rather, such differences may be more attributable to segmentation between these quasi-professional labor markets vis-a-vis the more traditional academic disciplines. This control seems especially appropriate in the case of business and engineering faculties.

On a more technical note, each equation in both systems is overidentified through the use of zero restrictions. We excluded an exogenous variable from an equation when we could find no theoretical justification for its inclusion other than its influence on another endogenous variable. As examples, the size of a school's endowment might alter output but only through facilitating capital expansion, scholarships, faculty salaries, and so forth. Similarly, tuition, research expenditures, scholarships, and loans affect student and faculty decisions but not output, ceteris paribus. And endowment is excluded from the student quality equation since the manifestations of a large endowment (campus beauty, faculty size and quality) are much more obvious to students than is the endowment itself. The identification issue is considered further in Section III.

II. Empirical Results

Table 2 contains three sets of results for the endogenous variables Q, S, and F. Model 1 reproduces the findings of our original study (Q = Ph.d.'s, n = 174). Model 2 is identical in specification but is estimated with the multiple-degree output measure and enlarged sample size (Composite Q, n = 336). Model 3 is expanded to incorporate the new variables which control for vocationally oriented curricula in the output and faculty equations. The models are estimated with a three-stage technique as a correction for

Table 2: Results of Three-Stage Least Squares Estimation

Variable \ Equation	Model 1: Q=PhD's; n=174 Q	S	F	Model 2: Composite Q, n=336 Q	S	F	Model 3: Composite Q; n=336 Q	S	F
Output (Q)		-3.52	0.01		0.75	-0.08		2.48**	-0.10
		(1.59)	(0.19)		(0.65)	(2.04)		(2.74)	(2.96)
Student (S)	-0.02		0.02**	0.05*		0.04**	0.05*		0.04**
	(1.13)		(7.95)	(1.80)		(9.58)	(1.82)		(10.33)
Faculty (F)	1.24*	21.98**		1.29*	22.90**		0.87	18.40**	
	(2.04)	(4.12)		(1.69)	(5.35)		(1.10)	(4.97)	
Tuition (T)		29.72**			6.64			5.42	
		(4.00)			(1.24)			(1.13)	
Endowment (E)			0.05**			0.04*			0.04*
			(2.95)			(1.98)			(2.07)
Capital (K)	0.08	2.45*	-0.12**	0.31*	3.32**	-0.17**	0.20	2.41*	-0.16**
	(0.07)	(1.91)	(2.86)	(1.87)	(2.68)	(3.74)	(1.32)	(2.09)	(3.52)
Academic (AC)	3.96**	45.24*	-0.35	6.28**	-13.76	0.83	6.94**	-26.03	1.04
	(2.49)	(1.93)	(0.52)	(2.90)	(0.69)	(1.18)	(3.43)	(1.41)	(1.51)
Research (RE)			0.03			0.01			0.02
			(1.73)			(1.14)			(1.24)
Administration (ADM)	3.92**			2.98**			1.87**		
	(4.59)			(3.52)			(2.45)		
Scholarship (SCH)		-34.72**			-1.52			-3.60	
		(2.77)			(0.26)			(0.56)	
Loans (L)		-8.89			2.36			1.34	
		(1.53)			(0.75)			(0.42)	
Faculty/Student Ratio (FSR)	2.09**	22.93**	-0.57**	1.54**	1.62	-0.10	1.32**	-1.35	-0.04
	(4.33)	(3.15)	(2.80)	(2.84)	(0.33)	(0.60)	(2.61)	(0.29)	(0.22)
Undergraduate Special. (USR)	0.16**	1.78**	-0.04**	0.20**	0.49	-0.02	0.16**	0.04	-0.01
	(3.31)	(3.05)	(2.58)	(3.85)	(0.97)	(1.19)	(3.37)	(0.10)	(0.76)
% Male Students (%MSTUD)	0.06*	0.92**		0.18**	0.31		0.22**	0.05	
	(2.30)	(2.83)		(6.23)	(1.25)		(7.11)	(0.19)	
% Business Majors (%BUS)							-0.18**		0.01
							(3.23)		(0.92)
% Engineering Majors (%ENG)							-0.25**		0.00
							(3.49)		(0.27)
% Education Majors (%ED)							-0.05		-0.02
							(0.71)		(1.51)
North Atlantic State (NA)			0.85*			0.17			0.28
			(2.13)			(0.84)			(1.29)
Great Lakes State (GL)			0.61*			-0.09			-0.02
			(1.73)			(0.69)			0.12
Western State (W)			0.94*			-0.22			-0.18
			(2.00)			(1.17)			(0.71)
Intercept	-37.30**	67.59**	7.97**	-111.56	481.13	-17.73	-95.27	642.89	-21.22
	(5.76)	(0.51)	(2.59)	(8.90)	(3.89)	(3.51)	(6.41)	(6.18)	(4.26)
Standard Error	5.20	68.28	1.93	8.59	77.02	3.04	8.09	72.96	3.15

Note: Numbers in parentheses are t-values.
* Denotes significance at the 0.05 level.
** Denotes significance at the 0.01 level.

the presence of error correlation across equations.

In light of the rather extensive scaling of variables as described in Table 1, it is useful to explain briefly the intuitive interpretation of the parameter estimates. Consider the coefficient .05 for student quality (S) in the output equation (Q) of Model 2. This coefficient suggests that a school with 1000 full-time undergraduate-equivalent students (FUE) raises its output of M.D., J.D., and Ph.D. alumni by .5 per decade for each 1 point increase in the third quartile SAT score of the entering freshman class. Thus, a 100 point increase in SAT results in 50 more graduate-degree alumni per decade.[6] In a similar vein, the coefficient on Academic expenditure suggests that a $10,000 increase in outlays (i.e. $1000/100 FUE enrollment where, for example, FUE = 1000) would raise alumni output by 62.8 per decade. Generally speaking, the correct interpretation of the coefficients requires careful recollection of the fact that inputs are scaled per 100 FUE students, and output is per FUE students per decade.

We turn now to a comparison of the results obtained in Models 1 and 2. Generally, the results in the output equation (Q) in both models foster a rather palpable notion of the baccalaureate process culminating in successful graduate-degree candidates. Note that faculty quality (F), academic (AC) and administrative (AD) support, a high faculty-student ratio (FSR), and undergraduate specialization (USR) are all statistically significant inputs in undergraduate production as measured by alumni career achievement. In short, the parameters in the output equations in Models 1 and 2 suggest a

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[6]This and subsequent illustrations consider only direct effects while holding other endogenous variables constant. However, due to the significance of other endogenous variables, the total effect throughout the system is actually greater.

production relationship in which relatively well-paid professors with relatively small classes and good libraries combine with a well-financed administration in a largely undergraduate environment to produce doctoral and law candidates.

In a broad sense, the original model appears relatively robust. Moving from a single to a multiple-career output measure, along with the increased sample, has not dramatically altered the results of the output equation. Nonetheless, there are several noteworthy differences which surface. Certainly the most encouraging of these is that student quality, previously negative and insignificant in Model 1, becomes positive and significant in Model 2. Obviously, this was one striking anomaly within our original findings. At that time, we conjectured that the seemingly inconsequential role of student quality on output might be accounted for by the use of median composite SAT score. We suggested that median student quality might not be a good indicator of academic potential which is latent in, say, only the upper quartile of the student population. Accordingly, the revised data set casts student quality as third quartile SAT scores. The new student quality coefficient in the output equation appears to corroborate the conceptual importance of the data adjustment.

A comparison of the student quality equations in Model 1 and 2 reveals that the impact of the enhanced data set is mixed. In Model 1, the significant parameters indicate that better students are drawn to schools where the undergraduate ratio is high, classes are small, and the quality of faculty is high. For example, in Model 1 the direct impact of a $1,000 increase in associate professor salary is to raise median SAT score of the entering class by 21.98 points. Further, note that the strong faculty impact survives with remarkable uniformity in Model 2. Similarly, the physical amenities of the campus as measured by the capital stock (K) display comparable drawing power for quality students in both models. However, observe that the faculty/student ratio (FSR) and undergraduate specialization ratio (USR), both highly significant variables in the original estimation, fall out in Model 2. The drop in significance of FSR and USR with the broader output measure might suggest that the motivation to pursue a Ph.D. is more closely related to the intimacy of the undergraduate experience than in the case of doctors and lawyers.

Regarding the faculty equation, recall from the discussion in Section I that this equation could be viewed 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, quality students and the financial security of a school's endowment appear to draw quality faculty. From a factor demand standpoint, the uniformly negative and significant sign on capital in both models suggests that administrators view the quality of the physical facilities as a substitute for quality faculty. Furthermore, the resource trade-off between well paid faculty and class size is suggested by the significant negative coefficient on faculty-student ratio in Model 1, although this relationship fades in Model 2. Similarly, the higher resource costs of graduate vis-a-vis undergraduate faculty is implied by the significant negative coefficient on undergraduate specialization ratio, but this relationship also wanes in Model 2.

As an interim summary, one might conclude that, despite certain exceptions. the simultaneous model of college production survives rather well using the composite career output measure and expanded sample. The next phase of this study is foreshadowed in Model 3. We plan to extend the model with respect to additional variables and, possibly, a fourth equation. Such an extension necessitates additional estimation considerations. Consequently, we defer discussion of Model 3 results until the next section.

III. Estimation Considerations

An important finding in our earlier study was the substantial amount of simultaneity among our three endogenous variables. In contrasting ordinary least-squares (OLS) estimates with three-stage least-squares (3SLS) estimates, we observed that coefficients for exogenous variables remained broadly similar in sign, magnitude, and significance under both techniques. However, coefficients for the endogenous variables changed markedly. Under OLS, student quality (S) was positively and significantly related to output (Q) while faculty quality (F) was not. As can be seen for Model 1 in Table 2, these roles were reversed in the 3SLS results. Furthermore, while university's output level appeared to attract quality students under OLS, it was statistically insignificant in simultaneous estimation. Finally, the coefficient for faculty quality in the student equation of Model 1 was double that of the OLS estimate.

Explaining the cause for these changes required consideration of both potential sources of bias in OLS estimation: correlation of endogenous variables with the error term, as well as the correlation of errors across equations. Examination of the statistical significance of the endogenous variables together with the estimated cross-equation correlations led us to conclude that the latter provided the dominant source of bias in the OLS estimates.

Having convinced ourselves of the need for simultaneous estimation, we now consider, in a preliminary manner, several other econometric issues. The first of these is the sensitivity of our results to the instrumental variables we utilize. This issue arises because in the process of expanding our sample, we have also collected a number of additional variables. While it is premature to incorporate most, the distribution of the student body by major has been checked and cleaned. Thus, Model 3 in Table 2 differs from Models 1 and 2 by its inclusion of the percents of the student body majoring in business, engineering, and education. As anticipated, the larger the portion of students majoring in business and engineering, the lower is college output as we define it. Surprisingly, however, a school's focus on these majors appears to play no statistically significant role in faculty salary determination. More interesting from the present perspective, is the effect of these additional instruments on the endogenous variables. The role of output in attracting quality students increases from insignificant in Model 2 (coefficient of 0.75 with a t-value of 0.65) to substantive in Model 3 (2.48 with t-value of 2.74). Other changes are less dramatic. Apparently, the instruments chosen are important in this model.

Furthermore, the exclusion restrictions used for identification may have an impact on parameter estimates. A set of estimates which are not presented are the results when including these majors in all three equations. Model 3 excludes them from the student quality equation because we can see no strong reason why business, engineering or education students should, on average, be better or worse in composite SAT than other students. Nevertheless, we are interested in the impact of their inclusion on our estimates. In comparison with Model 3, student quality drops to insignificance in the output equation, and output drops to insignificance in the student equation. Clearly, the manner in which the model is overidentified affects parameter estimates.

A third econometric issue might help to resolve the first two.

Specifically, the endogenous variables in this system might be treated better as unobservable. For example, the quality of university output, even under our restricted definition of career achievement, cannot be observed directly for the typical student. Consequently, we have used subsequent Ph.D, M.D., or J.D. attainment as an indicator of career achievement. Unfortunately, this number is affected by factors unrelated to quality. For example, our output measure is biased against predominantly female institutions and institutions specializing in the aforementioned vocationally-oriented majors. Similarly, the use of faculty salary as an indicator of the appropriate latent variable, faculty quality, has much to commend it. Nonetheless, many factors influence salary beyond quality in the context of undergraduate education. Cost-of-living differentials, market discrepancies by discipline, and higher graduate-faculty salaries all impact on the average salary at a school. Controlling for these factors in the structural equations actually "controls them into" the reduced form equations. Consequently, the second and third stages estimators retain these undesired, non-quality influences.

As we consider more of these factors, we propose to reformulate the model in an unobservables context. In particular, the LISREL[7] (linear structural relationships) model will be employed. LISREL is a full-information, maximum-likelihood technique which considers a measurement model for latent endogenous and/or exogenous variables within the broader context of a system of structural equations. For example, the measurement equation for faculty quality might specified as:

(6) $\text{SALARY} = b_0 + b_1 (\text{LATENT-F}) + b_2\, \text{USR} + b_3\, \%\text{BUS} + b_4\, \%\text{ENG}$

[7]See Joreskog and Sorbom (1984) for a detailed discussion of the LISREL model, its assumptions, and the computer program.

$$+ b_8 \%ED + v,$$

where v is a disturbance assumed to be normally distributed with zero mean, constant variance, and independent of errors in the structural equations. LATENT-F would then be used in place of SALARY for faculty quality (F) in the structural model.

IV. Concluding Remarks

This paper represents an intermediate product in an ongoing modeling of the higher educational process at private, predominantly undergraduate institutions. Looking to the past, this paper extends an earlier article by expanding the universe of schools to the full set instead of merely the best 225 in terms of baccalaureate Ph.D.'s. Correspondingly, we have nearly doubled the sample size. We have also broadened the career achievement measure to include M.D.'s and J.D.'s in addition to Ph.D.'s. The results have been encouraging. The composite picture of the earlier study survives. The role of human capital in the form of students, faculty and administrators emerges even stronger than previously. Academic expenditures continue to buttress the human element, while capital is apparently more important to the preparation for medical and legal studies than for the Ph.D.

Looking to the future, this paper has considered several econometric complications of expanding the model. By examining a preliminary extension, we have concluded that parameter estimates for the endogenous variables are affected by both the instruments selected and the exclusion restrictions imposed. These additional instruments were included to control non-qualitative influences out of the model. Indeed, several such controls are already in the model and many of the variables under consideration also fall into this category. Unfortunately, three-stage least-squares estimation does not remove such influences from the model. This has led us to consider an alternative estimation strategy. We intend to recast the current endogenous variables as merely the observed effects of the true, but unobserved, quality measures. Such a treatment will enable us to control adequately for non-qualitative differences between their observed counterparts.

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