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Economies of Scale in Large Academic Libraries

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This paper attempts to determine whether economies of scale exist in large four-year public and private academic libraries in the United States. Using different criterion to define a large academic library and also using two conceptually different models to measure library output, the paper concludes that for both models there are definite economies of scale in these libraries.

INTRODUCTION

The cost of library service is a concern of every library administration. This paper analyzes how costs vary with changes in the amount of service provided by large academic libraries in the United States. It focuses on whether the average cost of providing a unit of service rises less rapidly than output (the case where economies of scale occur) or rises more rapidly than the increases in service volume (diseconomies of scale).

The likelihood of there being economies of scale in large academic libraries is consistent with the general knowledge that costs decline with increased output. As organizations become larger, there is a greater chance for specialization of skills, a greater likelihood that automation techniques can be used effectively, and a greater chance of cost reductions in acquiring supplies and equipment for operations.

On the other hand, large organizations may have larger administrative units, may acquire more specialized materials which are expensive and difficult to process, and may be burdened with complex procedural and institu-

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tional arrangements. This later set of factors can serve to increase costs as output increases. If economies of scale are found in large academic libraries, it may have significant bearing on planning and networking. So it is appropriate that this research specifically address the cost-output relationships in large academic libraries.

There are two reasons for continued research into economies of scale in academic libraries. First, a previous paper (Cooper, 1983), comparing operating costs of academic libraries to output, found no economies of scale. However, on a closer examination of the cost-output relation for libraries with the largest output, costs did decline slightly, though the regression results indicated the overall trend to be in the direction of diseconomies of scale.

The second reason for this research is to explore two conceptually different models to determine if economies of scale exist in academic libraries. Generally, there are two primary functions performed by large academic libraries: the archive and access functions. The archive function involves accumulating the large quantity of literature produced for a variety of academic disciplines and preserving it for future generations of scholars. The access function is that of acquiring materials and making them available to users for immediate use. Clearly, a large academic library does not do one to the exclusion of the other.

The research reported here formulated two different mathematical models corresponding to the two functions described above and analyzed whether economies of scale existed using each model. In general, the approach was to form an equation which related total cost of operating a library to the output produced by the library. The output measures used in Model I—the archive model of library service—included the number of volumes added to the library's collection in a given year, the number of reference questions answered, the number of items circulated, the number of hours the library was open per week, and the number of interlibrary lending and borrowing transactions performed. Model II—the access model—included all of the variables above with the exception of the variable, volumes added to the collection.

The way the volumes-added output measure is viewed is a fundamental point in analyzing economies of scale. By including volumes added in the first equation, one is saying that some of the work done by a library's technical processing operation is the final output of the library. That is, some materials may never or seldom be circulated, be used in answering a reference question, or be used in an interlibrary lending request. If the item is not counted in the technical processing output, total output will be understated by the proportion of the collection that is processed to support the library's archive function but that is not being used.

Clearly, there is a problem with double counting or omission. In Model I, for example, we may be counting an item during technical processing and circulation. On the other hand, in Model II we may be completely omitting items that are never accessed by users. Until it is possible to more clearly differentiate in a quantitative way whether we are omitting or double counting, the extent of the impact of either will be difficult to assess.

METHODOLOGY

Both Models I and II use institutional data from 1977 collected by the National Center for Educational Statistics on college and university libraries in the United States. (Beasley, 1980). From more than 3000 academic libraries of all types, 1908 were selected as four-year public or private college and university libraries.

This research analyzes only the largest of these institutions. A number of criterion were used to determine the largest institutions. Ranked lists were produced based on libraries with the largest volumes held, greatest operating expenditures, highest circulation, and sizes of professional and total staff. In addition, a list of Association of Research Libraries (ARL) member libraries was extracted. Arbitrary cut-offs were applied to each list to select the largest libraries by each classification variable, making six samples of libraries available for analysis. The extent of overlap of these institutions and the cut-off values used are discussed in the section on the uniqueness of the sample. The six samples of academic libraries (ARL libraries; largest libraries as measured by volumes held, operating expenditures, circulation, size of professional staff, and total staff size) were then analyzed to see whether economies of scale were present using either Model I or Model II.

The mathematical model that served as a basis for the analysis of Model I had the functional form:

$$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6$$

where Y is the total operating expense and X_1 represents volumes added, X_2 represents reference transactions, X_3—circulation, X_4—hours opened, X_5—interlibrary lending, and X_6—interlibrary borrowing. The a's and b's in the equation are constants and ln is the natural logarithm of the value. The difference between this equation and the one used for Model II was that in Model II the X_1 term was omitted.

When the logarithmic form of the equations are used, the equations have the property that the sum of the b_i coefficients indicate the presence ($\Sigma b_i < 1$) or absence ($\Sigma b_i > 1$) of economies of scale.

Ordinary Least Squares regression analysis was performed to fit the equations to the data.

THRESHOLD ANALYSIS

In selecting the samples, a ranked list of libraries based on one of the five criterion variables was produced. Then subjective judgments were made to break the list into the largest institutions. Table I summarizes the criterion used to select the libraries for the samples. In the case of the ranked list of libraries by volumes held, Harvard led the list with 9.5 million volumes (followed by Yale, Illinois, Minnesota, and Berkeley), while the institution at rank 100 (University of Delaware) held 1.1 million volumes. An arbitrary cut-off was applied at 1.5 million volumes, and the sample that resulted contained 62 libraries. Similarly, the sample of large libraries ranked by operating expense ranged from one with $14.4 million in expenditures (Harvard) through one with $4.0 million (Virginia Polytechnic).

Forty-eight libraries were included in the sample based on libraries with large circulations (where 600,000 items circulated was set as the cutoff), and 40 and 45 libraries, respectively, were included in the sample based on the sizes of the library's professional staff and on its total staff.

Though the samples selected were from the largest academic libraries in the United States, there is still considerable variability within each of the data values. For example, the sample based on circulation contains 48 libraries but the range of circulation values in the sample is from 2.1 million to 600,000 items circulated per year. Likewise, the professional staff in the institutions ranged from 209 to 30.

This research confronted a conceptual problem in exploring a phenomenon related to size, namely economies of scale, and then preselecting

TABLE I
Thresholds Used to Establish Five Library Samples

Criterion Variable	*Highest Value in Population*	*Value of Criterion Variable at Rank 100*	*Cutoff Value applied to Criterion*	*Sample size resulting from Cutoff*
1. Volumes held	9,547,576	1,067,964	1,500,000	62
2. Operating Expenditures	14,362,801	2,381,433	4,000,000	43
3. Circulation	2,118,899	370,441	600,000	48
4. Total Professional Staff	209	19	30	40
5. Total Staff Size	1,375	63	100	45

by size only certain institutions to analyze. Even though the samples are relatively small, the range of values within each criterion variable is large. Thus the bias of selecting only institutions by size is present in theory, but in practice the variability in even the largest institutions mitigates against this being a serious problem.

UNIQUENESS OF SAMPLES

Six samples of libraries were selected for analysis. Table II lists the institutions and for each of the six samples indicates the relative ranking of the institutions within the sample. For example, institution number 8 is the University of California, Berkeley. It is an ARL member, had the fifth largest number of volumes held of all institutions in the sample, and was second largest in both size of operating expenses and circulation. The final column of the table gives the number of times the institution was included in one of the six samples, which in the case of Berkeley, was in all six.

The combined total of institutions in all samples is 134. Out of this number, 56, or 42 percent, appear in only one sample, while 58 percent appear in more than one sample. Twenty-two institutions were in two samples, 23 in three samples, and 15 in four. There were 9 institutions that were in five samples. The 9 libraries that were on all six lists were the University of California, Berkeley; Yale; Harvard; Michigan State; University of Michigan, Ann Arbor; Cornell; Ohio State; University of Washington; and the University of Wisconsin.

Cutoff points were subjectively determined for the samples. It is possible to judge the quality of the cutoff decisions by briefly reviewing why certain libraries were included in each sample. Of the 56 libraries on a single list, 22 were included only because of their membership as ARL libraries, but did not meet any of the other criterion for large academic libraries. This evidence suggests that membership in the ARL is not consistent with measuring size of an institution when compared to size based on volumes held, operating expenses, and the other three variables.[1]

Out of these same 56 libraries that appeared on a single list, 21 were included because they fall within the criterion for inclusion based on total staff size, 12 on the basis of professional staff size, and one on the basis of circulation size.

[1]ARL has recently adopted a new criterion for determining membership in its Association. See Mekkawi (1982). The criterion is based on the ARL Library Index which computes an index value for each library based on volumes held and added; microforms held and added; serials received; expenditures for materials, binding, salaries and wages, and other items; and number of FTE professional and paraprofessional staff. The result of applying the Index to the data in this report may very well considerably change the ARL membership list.

TABLE II
Rankings of Institutions in Six Samples of Large Libraries

Institution Name	ARL Member	*Rank of Institution by Criterion Variable*					Number of Occurrences in the Samples
		Volumes Held	Operating Expenses	Circulation	Total Professionals	Total Staff	
Alabama							
1 The U of Alabama	Yes	.	.	.	.	.	1
Arizona							
2 Arizona State University	Yes	.	.	21	.	.	2
3 University of Arizona	Yes	32	27	29	.	.	4
California							
4 Cal State U-Los Angeles	.	.	.	37	.	41	2
5 San Diego State U	.	.	.	48	.	44	2
6 San Francisco State U	.	.	.	35	.	14	2
7 Stanford University	Yes	9	5	15	.	.	4
8 U of Cal-Berkeley	Yes	5	2	2	1	4	6
9 U of Cal-Davis	Yes	45	14	20	.	8	5
10 U of Cal-Irvine	Yes	.	.	.	.	.	1
11 U of Cal-Los Angeles	Yes	6	3	6	13	.	5
12 U of Cal-Riverside	Yes	.	.	.	.	.	1
13 U of Cal-San Diego	Yes	.	28	44	.	.	3
14 U of Cal-San Francisco	.	.	.	.	.	16	1
15 U of Cal-Santa Barbara	Yes	53	29	.	.	29	4
16 U of Cal-Santa Cruz	.	.	.	.	.	11	1
17 U of Southern California	Yes	46	36	28	.	.	4
Colorado							
18 Colorado College	.	.	.	.	21	.	1
19 Colorado State University	Yes	.	.	.	.	.	1
20 U of Colorado at Boulder	Yes	56	.	42	.	.	3
Connecticut							
21 Southern Conn St College	.	.	.	.	8	.	1
22 U of Conn Main Campus	Yes	.	.	.	.	5	2
23 Yale University	Yes	2	4	16	25	26	6
District of Columbia							
24 Georgetown University	Yes	.	.	.	.	.	1
25 Howard University	Yes	.	.	.	.	.	1
Florida							
26 Florida State University	Yes	44	.	30	.	.	3
27 University of Florida	Yes	28	39	.	17	.	4
28 University of Miami	.	.	.	.	.	32	1
Georgia							
29 Emory University	Yes	.	.	.	.	.	1
30 University of Georgia	Yes	48	34	.	.	.	3
Hawaii							
31 U of Hawaii at Manoa	Yes	57	37	.	.	.	3
Illinois							
32 Nthestn Ill University	.	.	.	.	32	.	1
33 Loyola U of Chicago	.	.	.	.	.	39	1
34 Luth Sch Theology Chicago	.	.	.	.	33	.	1
35 Northwestern University	Yes	21	30	45	.	.	4

continued

TABLE II (Cont'd.)

Institution Name	ARL Member	*Rank of Institution by Criterion Variable*					Number of Occurrences in the Samples
		Volumes Held	Operating Expenses	Circulation	Total Professionals	Total Staff	
Illinois (cont'd)							
36 Sthn Illinois U Carbondl	Yes	47	25	.	.	.	3
37 University of Chicago	Yes	11	15	26	.	2	5
38 U of Ill Medl Ctr Chgo	.	.	.	.	.	20	1
39 U of Ill Urbana Campus	Yes	3	12	5	5	.	5
Indiana							
40 Ball State University	.	.	.	40	.	34	2
41 Indiana U at Bloomington	Yes	13	19	13	.	.	4
42 Purdue U Main Campus	Yes	.	.	36	.	45	3
43 University of Notre Dame	Yes	.	.	.	.	.	1
Iowa							
44 Iowa State U Sci & Techn	Yes	.	.	31	.	38	3
45 University of Iowa	Yes	22	31	25	.	.	4
Kansas							
46 U of Kansas Main Campus	Yes	25	.	19	.	33	4
Kentucky							
47 University of Kentucky	Yes	52	.	.	.	.	2
Louisiana							
48 LA State U and A&M C	Yes	35	.	.	.	27	3
49 Tulane U of Lousiana	Yes	40	.	.	.	18	3
Maryland							
50 Johns Hopkins University	Yes	26	41	.	.	36	4
51 U of MD College Park Cam	Yes	55	23	23	.	21	5
52 Western Maryland College	.	.	.	.	24	.	1
Massachusetts							
53 Boston University	Yes	.	.	.	.	.	1
54 Harvard University	Yes	1	1	3	2	1	6
55 Mass Inst of Technology	Yes	51	.	.	.	22	3
56 U of Mass Amherst Campus	Yes	60	.	47	.	.	3
Michigan							
57 Madonna College	.	.	.	.	22	.	1
58 Michigan State University	Yes	29	35	17	34	37	6
59 U Michigan-Ann Arbor	Yes	7	6	11	6	5	6
60 Wayne State University	Yes	31	33	.	.	.	3
Minnesota							
61 U of Minnesota Duluth	Yes	.	.	.	.	.	1
62 U of Minn Mnpls Snt Paul	.	4	10	10	.	.	3
Missouri							
63 U of Missouri Columbia	Yes	36	.	.	.	.	2
64 Washington University	Yes	41	.	.	.	.	2
65 William Jewell College	.	.	.	.	26	.	1
Nebraska							
66 U of Nebraska at Omaha	Yes	.	.	.	.	.	1
Nevada							
67 U of Nevada Reno	.	61	.	.	30	.	2

(continued)

TABLE II (Cont'd.)

Institution Name	ARL Member	*Rank of Institution by Criterion Variable*					Number of Occurrences in the Samples
		Volumes Held	Operating Expenses	Circulation	Total Professionals	Total Staff	
New Hampshire							
68 Dartmouth College	Yes	.	.	.	.	.	1
69 Saint Anselm's College	.	.	.	.	35	.	1
New Jersey							
70 Drew University	.	.	.	.	29	.	1
71 William Paterson College	.	.	.	.	18	.	1
72 Princeton University	Yes	19	18	41	.	13	5
73 Rutgers U Newark Campus	Yes	.	.	.	.	.	1
74 Rutgers U New Brunswick	.	17	22	33	.	.	3
New Mexico							
75 NM State U Main Campus	Yes	.	.	.	.	.	1
76 U of NM Main Campus	Yes	.	.	16	.	.	2
New York							
77 Adelphi University	.	.	.	.	.	31	1
78 CUNY Brooklyn College	.	.	.	.	.	9	1
79 CUNY Queens College	Yes	.	.	.	.	24	2
80 Columbia U Main Division	Yes	8	9	14	.	.	4
81 Cornel U Endowed Colleges	Yes	18	20	27	10	17	6
82 Jewish Theol Sem America	.	.	.	.	16	.	1
83 Manhattan College	.	.	.	.	36	.	1
84 Mercy College	.	.	.	.	37	.	1
85 New York University	Yes	24	26	.	.	.	3
86 Sarah Lawrence College	.	.	.	.	12	.	1
87 SUNY at Albany	Yes	.	.	.	.	.	1
88 SUNY at Buffalo Main Cam	Yes	33	38	.	31	.	4
89 SUNY at Stony Bk Main Cam	Yes	.	.	.	26	.	1
90 Syracuse U Main Campus	Yes	50	.	.	.	.	2
91 University of Rochester	Yes	49	.	43	.	.	3
92 Yeshiva University	.	.	.	4	.	.	1
North Carolina							
93 Duke University	Yes	23	42	.	9	.	4
94 U of NC at Chapel Hill	Yes	12	21	22	.	.	4
Ohio							
95 Case Western Reserve U	Yes	54	.	.	27	.	3
96 Kent State U Main Campus	Yes	.	.	.	.	.	1
97 Miami University Main Cam	Yes	.	.	.	40	.	2
98 Ohio State U Main Campus	Yes	14	13	6	14	6	6
99 U of Cincinnati Main Cam	Yes	.	.	.	.	.	1
Oklahoma							
100 Central State University	.	.	.	.	.	25	1
101 Okla State U Main Campus	Yes	.	.	.	.	.	1
102 U of Oklahoma Norman Cam	Yes	42	.	.	.	.	2
Oregon							
103 U of Oregon Main Campus	Yes	59	.	39	4	23	5
Pennsylvania							
104 Cedar Crest College	.	.	.	.	19	.	1

(continued)

TABLE II (Cont'd.)

Institution Name	ARL Member	*Rank of Institution by Criterion Variable*					Number of Occurrences in the Samples
		Volumes Held	Operating Expenses	Circulation	Total Professionals	Total Staff	
Pennsylvania (cont'd)							
105 Haverford College	.	.	.	.	.	43	1
106 PA State U Main Campus	Yes	27	16	46	.	.	4
107 Widener College	.	.	.	.	20	.	1
108 Swarthmore College	.	.	.	.	.	28	1
109 Temple University	Yes	62	40	.	.	.	3
110 U of Pennsylvania	Yes	20	17	.	.	.	3
111 U of Pittsbg Main Campus	Yes	34	32	.	.	.	3
112 Villanova University	Yes	.	.	.	.	.	1
Rhode Island							
113 Brown University	Yes	43	.	.	.	.	2
South Carolina							
114 U of SC Main Campus	Yes	58	.	38	.	.	3
Tennessee							
115 East Tenn St. University	.	.	.	.	15	.	1
116 U of Tennessee Knoxville	Yes	.	.	7	.	.	2
Texas							
117 Rice University	Yes	.	.	.	.	.	1
118 Texas A&M U Main Campus	Yes	.	.	16	.	.	2
119 Texas Christian U	.	.	.	.	.	35	1
120 Texas Tech University	.	.	.	.	.	40	1
121 U of Houston Cen Campus	Yes	.	.	.	.	.	1
122 U of Texas at Austin	Yes	10	7	1	.	3	5
Utah							
123 Brigham Young U Main Cam	Yes	.	.	24	.	.	2
124 University of Utah	Yes	37	.	.	.	.	2
Virginia							
125 U of Virgina Main Cam	Yes	30	24	34	.	15	5
126 VA Poly Inst and State U	Yes	.	43	.	.	.	2
Washington							
127 Evergreen State College	.	.	.	.	23	.	1
128 University of Washington	Yes	16	8	9	7	12	6
129 Washington St University	Yes	.	.	.	38	.	2
Wisconsin							
130 U of Wisconsin Madison	Yes	15	11	12	3	10	6
131 U of Wisconsin Plattevl	.	.	.	.	11	.	1
132 U of Wisconsin Stevns Pnt	.	.	.	.	39	.	1
Wyoming							
133 University of Wyoming	.	38	.	.	.	.	1
Puerto Rico							
134 U of PR Rio Piedras	.	39	.	32	.	19	3

It would appear that since there are a large number of libraries on the list only because of the size of their total staff, the cutoff level for this variable may have been set too low. However, where there is a large repetition of institutions in the various samples, the reverse conclusion is reached. Nine libraries were found in five out of six samples. All but one library would have been in all six samples if the cutoff for professional and total staff had been lower. Thus there is a problem with the criterion set for total staff, but no clear indication that it should have been changed one way or another. A balance appears to have been reached.

EXPERIMENTAL RESULTS

In contrast to previous research which analyzed academic libraries of all sizes (Cooper, 1982), this experiment found that for the largest four-year academic libraries in the United States, definite and strong indicators of economies of scale are present. The extent to which economies of scale are present is measured by the sum of the b_i coefficients. As can be seen in Table III (Model I) and Table IV (Model II), the sum of the b_i's are less than one for all six samples of both models.

The greatest economies of scale for Model I and Model II occur in the sample of the largest libraries ranked by operating expenditures. Here the sum of the b_i values are .12 and .11, respectively, indicating that costs decline strongly as size increases.

Another sample that has large economies of scale for both models are libraries with the largest circulation. While not as low as the operating expenditures group, this sample still had a very low value for the sum of the b_i's for both models (.25 for Model I and .34 for Model II).

The explanatory power of the equations is measured by the value of R^2. The R^2 values for Model I are generally higher (.82—.95) than those for Model (.60—.79) including that the equations in Model I explain more of the variation in the dependent variable (total cost) than Model II. The fit of both models' equations to the data is very good, but the model that includes volumes added as an output measure explains more of the variation than the one without it. Thus it is concluded that Model I is conceptually a better model than Model II for this set of samples of large academic libraries.

Three additional statistical values are reported in Tables III and IV. They are the values of the F-ratio, the Durbin-Watson D statistic, and the autocorrelation coefficient. The F-ratio measures the overall significance of the regression equation, and in all cases the equations were found to be significant at the $\alpha = .001$ level.

The two models tested in this paper related total operating expenditures to measures of output. The regression procedures allow testing to determine whether the output measures are significant in explaining varia-

TABLE III
Economies of Scale Regression Analysis for Large 4-Year Academic Libraries—Model I

	ARL Libraries	*Largest Volumes Held*	*Largest Operating Expenditures*	*Largest Circulation*	*Largest Number of Professionals*	*Largest Total Employment*
Intercept	8.1656	8.3710	12.5650	11.6794	6.4429	9.0199
	(8.19)	(4.83)	(7.32)	(5.39)	(1.61)	(4.17)
b_1	0.5256*	0.4793*	0.2903*	0.6091*	0.8141	0.5931*
Volumes Added	(7.78)	(6.73)	(3.38)	(7.61)	(5.97)	(7.74)
b_2	0.0830*	0.0527	0.0028	0.0408	0.0759	0.1380*
Reference	(2.41)	(1.50)	(0.09)	(1.05)	(1.28)	(3.15)
b_3	0.0767	0.1287	0.2119	−0.0510	0.0611	0.0801
Circulation	(1.23)	(1.84)	(2.63)	(−0.50)	(0.57)	(1.54)
b_4	−0.1907*	−0.2555	−0.5088*	−0.4373*	−0.2575	−0.4162
Hours Open	(1.97)	(−1.42)	(−2.93)	(−1.83)	(−0.54)	(−1.65)
b_5	0.1340*	0.1674	0.0531	0.2077*	0.0501	0.0601
ILL	(3.71)	(4.44)	(1.36)	(3.99)	(0.85)	(1.48)
b_6	−0.0118	0.0027*	0.0749	−0.1212	0.0047	0.0526
ILB	(−0.26)	(0.05)	(1.46)	(−1.74)	(0.06)	(0.97)
R^2	.82	.85	.82	.85	.95	.93
Degrees of Freedom	80	57	39	42	33	39
F Ratio	55.4	48.3	24.4	33.1	88.9	67.2
Σb_i	.62	.58	.12	.25	.75	.51

tions in cost. Model I is composed of six independent variables and Table III shows that, depending on the particular sample analyzed, the number of significant variables in each sample ranges from a high of four for ARL libraries to one for libraries with the largest number of professionals. Likewise Model II has five independent variables. Both ARL libraries and libraries with highest total employment have three significant variables, while libraries with highest operating expenditures and circulation have only one.

In Model I, volumes added was always a significant variable in the equation for all samples, so when it was removed to form Model II, it was logical that the explanatory power of the equation (as measured by the value of R^2) would fall, and, in fact, it did.

Another interesting phenomenon can be observed in the equations by examining the relative values of the b_i coefficient values themselves. In Model I, the b_i coefficient with the largest absolute value is volumes added. Considering the conceptual base of the model, this outcome is reasonable. The model says that the archive and access function are important and that one has to attribute costs to acquisition as well as public service. In Model II the conceptual basis changes and emphasis is on access. here the weightings

of the b_i's change and the variable with the highest weighting is circulation.[2] Again, this is consistent because it says that as circulation increases (in the absence of counting volumes added), costs will increase and that circulation (among all the variables) is the most important in influencing costs.

It is also useful to analyze the effect of the variable hours-span on the equations. All of the b_i coefficients of the hours open term in all equations for both models are negative. When the b_i values are summed to determine the shape of the total cost curve and thus establish whether there are economies of scale, the value of the b_i coefficient value is subtracted from the total. Without considering hours open, the equation would show less economies of scale because the sum of the b_i's would be greater. When the b_i value for hours open is subtracted, the cost curve turns down and consequently there are more economies of scale. This conclusion is reasonable since the hours open variable reflects the amount of use of a fixed capital asset—the library building. As the facility is used more, the cost of use per day decreases.

TABLE IV
Economies of Scale Regression Analysis for Large 4-Year Academic Libraries—Model II

	ARL Libraries	*Largest Volumes Held*	*Largest Operating Expenditures*	*Largest Circulation*	*Largest Number of Professionals*	*Largest Total Employment*
Intercept	9.0767	8.3134	12.0141	10.8563	11.1638	7.5198
	(6.82)	(3.51)	(6.31)	(3.12)	(1.88)	(2.09)
b_2	0.1086*	0.0830	-0.0004	0.0891	0.1531	0.2164*
Reference	(2.35)	(1.74)	(-0.01)	(1.45)	(1.75)	(3.04)
b_3	0.3287*	.3977*	0.4013*	0.2459	0.5121*	.2520*
Circulation	(4.57)	(5.06)	(6.02)	(1.63)	(4.52)	(3.22)
b_4	-0.0453	-0.0846	-0.3241	-0.2584	-0.5947	-0.0224
Hours Open	(-0.36)	(-0.35)	(-1.72)	(-0.68)	(-0.83)	(-0.05)
b_5	0.2091*	0.1491*	0.0317	0.2878*	0.2292*	0.1812*
ILL	(4.47)	(2.90)	(0.72)	(3.51)	(2.98)	(2.90)
b_6	-0.0807	0.0362	0.0689	-0.0203	-0.1430	0.1246
ILB	(-1.36)	(0.52)	(1.17)	(-0.18)	(-1.23)	(1.39)
R^2	.67	.72	.76	.60	.89	.79
Degrees of Freedom	74	51	33	36	27	33
F Ratio	30.1	26.2	20.5	10.9	43.6	24.7
Σb_i	.52	.58	.11	.34	.16	.75

[2]One exception is the sample of libraries with largest circulation. The exception may be caused by the lack of variability of the data for that sample. But it seems unlikely that that is the case since Table I shows a large spread in circulation values.

SUMMARY AND CONCLUSIONS

Two conceptually different models have been presented to explain whether economies of scale are present in academic libraries. In Model I, the archive function of large academic libraries was stressed, and in Model II emphasis was on access to information. Both models related total costs of operating a library to the measures of output of a library. The measures of output for Model II included circulation, reference questions answered, hours open, and interlibrary lending and borrowing transactions. For Model I the additional variable, volumes added, was included to reflect work performed as part of the archive function.

The population of more than 3000 academic libraries in the United States was reduced to four-year public and private libraries, and six samples of the largest libraries were selected. The samples were made up of the libraries with the largest number of volumes held, the highest operating expenditures, the greatest circulation, and the biggest professional and total staff use. ARL libraries made up the sixth sample.

The results of the analysis confirm that for all samples of these large libraries there is strong presence of economies of scale. It indicates that as output increases, total costs increase less rapidly. The statistical results also confirm that Model I is better at explaining the variations in total cost than Model II.

REFERENCES

Beazley, R. M. (1980). *Library Statistics of Colleges and Universities, 1977: Institutional Data (Libgis III/Hegix XII).* U.S. National Center for Education Statistics, Washington, DC. Published by Department of Library Science, Indiana State University, Terre Haute, IN.

Cooper, M. D. (1983). Economies of scale in academic libraries. *Library and Information Science Research 5,* 207–219.

Mekkawi, M. (1982). The ARL library index as a decision-making tool. *College and Research Libraries 43,* 396–401.