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ABSTRACT

The relationship between the costs of central administration and academic teaching and research production was studied, based on a large sample of British universities and a separate analysis of the Free University of Brussels, Belgium. To determine variables important to central administration costs, a cross-sectional and intertemporal regression analysis was undertaken with data from the British universities. The fixed-variable cost method was used to estimate cost functions for the Free University of Brussels. For the British universities, 1969-79 through 1976-77 data were used, while 1978 figures were used for the Belgian university. It was found that resources needed for the central administration program in a university were related to student numbers in an indirect way. A significant part of total costs was fixed and did not depend on any activity parameter. These fixed costs consist mainly of salary expenditures for the leadership function of the different administration programs. Other variables than student number influenced the central administration requirements. This was true for the granted research activities and for the mix of fields of studies in a university. Granted research activities involved higher administration expenditures than teaching and teaching-related research activities. Experimental academic activities (represented by number of students or academic staff) required a more expensive central administration than did nonexperimental activities. Finally, it was found that marginal costs with respect to internal activity parameters were nonconstant. Results were relevant for universities with a size below 11,000 students. (SW)

A RESOURCE REQUIREMENTS PREDICTION MODEL FOR THE CENTRAL ADMINISTRATION SUPPORT PROGRAM IN A UNIVERSITY

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ABSTRACT

This paper investigates the influences on the cost of the central administration support program of a number of relevant basic variables, describing the teaching and research activities in a University. The parameters of regression equations estimated for British Universities, are compared with the respective parameters of formula estimated by means of an allocation matrix for a Belgian University. It is shown that a significant part of central administration costs is related to student numbers in a more indirect way than a more proportionality. The results can be used to improve the budget allocation process of governments and universities.

1. INTRODUCTION

The needs of resources for the central administration activities in a University have been analysed by some authors. Pickford (1975) made an intertemporal and cross-sectional regression analysis of the administration expenditures in a large number of British Universities for the period 1966-1971. He found a good relationship between expenditures and the number of students. Verry and Davies (1976) classified students into arts-based and science-based students. Last category was significantly more expensive. Both studies show that increases in organizational size tend to lower unit costs and thus yield economies of scale. R. Bouwen (1980) also confirms the existence of economies of scale for the central administration activities. Nevertheless economics will have no effect on total unit costs because institutions will shift any savings to new internal uses - for example creation of new programs, higher quality of programs etc.

This paper tries to investigate the relationship between the cost of the central administration and academic teaching and research production more thoroughly.
As to these academic outputs there is no widely accepted way to quantify them. So we used input-based quantities as independent variables. Numbers of students or numbers of academic staff are generally accepted as good activity parameters for teaching and teaching-related-research activities (internally financed academic activities). On the other hand the amount of research grants is considered a good index for externally funded research.

We first carried out a cross-sectional and intertemporal regression analysis of the data of a large sample of British universities to find the most appropriate variables determining in a significant way the cost of the central administration. The validity of constant marginal costs is tested by investigating cubic and quadratic cost functions. Finally we obtained a set of relevant cost-equations that estimate the theoretical budget for the central administration program relevant for British institutions.

In a second part we have tried to estimate cost-functions for a Belgian University, using the fixed-variable cost method. The same basic variables are used as in the British equations. Fixed costs were seperated from variable costs which were then allocated to the final academic programs by means of an "allocationmatrix"

The suitability of the British formula to Belgian Universities was investigated by comparing the coefficients of the corresponding independent variables of the respective cost functions.

2. DATA SOURCES

The major sources of data for the regression study are the statistics derived by the University Grants Commitee (U.G.C.) from the annual returns to the Commitee made by the individual universities of the United Kingdom. These data are published every year in the Statistics of Education, Volume 6 (universities).

In order to increase the size of the data sample we made a cross-sectional and intertemporal analysis. The years involved are 1969/70 - 1976/77. The data were adjusted to eliminate the influence of changes in the level of prices over time. The Tress-Brown index for total recurrent expenditures (see tabel 1) was used to produce constant price money variables of january 1977.

Some institutions (7 in total) were not included in this study because the data were not comparable to those of other universities. The excluded institutions are the same as in the analyses of Verry et al (1976) and Pickford (1975).

The only data available to us with enough detail for estimating cost functions for a Belgian university were these of our own institution, the Free University of Brussels (V.U.B.). The equations refer to 1978 - expenditures.

TABLE 1. *Evolution of Tress-Brown index (1)*

Year (1th jan)	index
1967	100.2
1968	102.6
1969	107.4
1970	118.4
1971	133.6
1972	144.9
1973	159.9
1974	174.9
1975	212.0
1976	266.0
1977	291.3

(1) Source : Comittee of vice-chancellors and principals, index of university cost.

3. METHODOLOGY AND RESULTS OF THE REGRESSION ANALYSIS

3.1. Methodology and approach

We have tried to formulate the relationship between total administration expenditures and one or more activity parameters more precisely by estimating the coefficients of a number of relevant equations each consisting of a different set of independant variables. The regression technique was used to estimate these relationships between costs and output-parameters.

The most natural starting point for estimating equations is the simple linear fonm with one or more independent variables :

$$TC=a_o + a_1X_1 + a_2X_2 \ldots + a_nX_n$$

This total cost function implies that there is a given set-up cost, represented by the constant term a_o and constant marginal costs $a_1, a_2, \ldots a_n$. A positive statistically significant constant term means that the administrative function of a Universit, organisation shows economics of scale with the grouth of its outputvolume. The extent of returns of scale in the linear cost function solely depends on the magnitude of the fixed cost term.

An other reason for estimating costs functions is to determine the marginal costs of the different outputs. Marginal costs, as defined in economics, is the change in total cost associated with producing one additional output. If one estimates a regression equation with the number of students as the only independent variable, the regression coefficient of the student-variable represents the marginal (or additional) administrative cost of an additional student. In the case of linear equations marginal cost are constant, thus independent of the output-volume. Marginal costs will not generate additional economies of scale. Average administration costs will decline only because the fixed cost is spread over a larger outputvolume.

The validity of the constant marginal cost hypothesis can also be tested using the regression technique. This is done by adding quadratic and cubic terms to the independent variables of the linear equations. If higher power terms of an independent variable are statistically different from zero the hypothesis of constant marginal cost is rejected. The exact form of marginal costs will depend on the signs and magnitudes of the higher power regression coefficients.

3.2. Results

3.2.1. *Linear cost functions*

A preliminary drawing of the scatter diagrams indicates a close relationship between central administration expenditures and student numbers (see figure 1). The diagram also reveals relative high fixed costs.
This relationship is not surprising ; as is told before student numbers are a good activity-index for the teaching and teaching-related research-activities of a University.

Regression number 1a of table 2 shows the results of a regression analysis with the number of students (S) as independent variable. The regression coefficient for the studentvariable and the constant term are both statistically very significant. The high significant value of the constant illustrates important economies of scale. The multiple correlation coefficient (R^2) is high and this means that the estimated equation gives a good fit to the data points. It also confirms the hypothesis that student-numbers are a good overall-index for university outputs.

Better results were obtained in estimating an equation with academic staff (AP) as independent variable (see regression number 1b of table 2) The multiple correlation coefficient increases from .82 to .86. This demonstrates that academic staff is a better overall-index for internal and external academic activities than students.

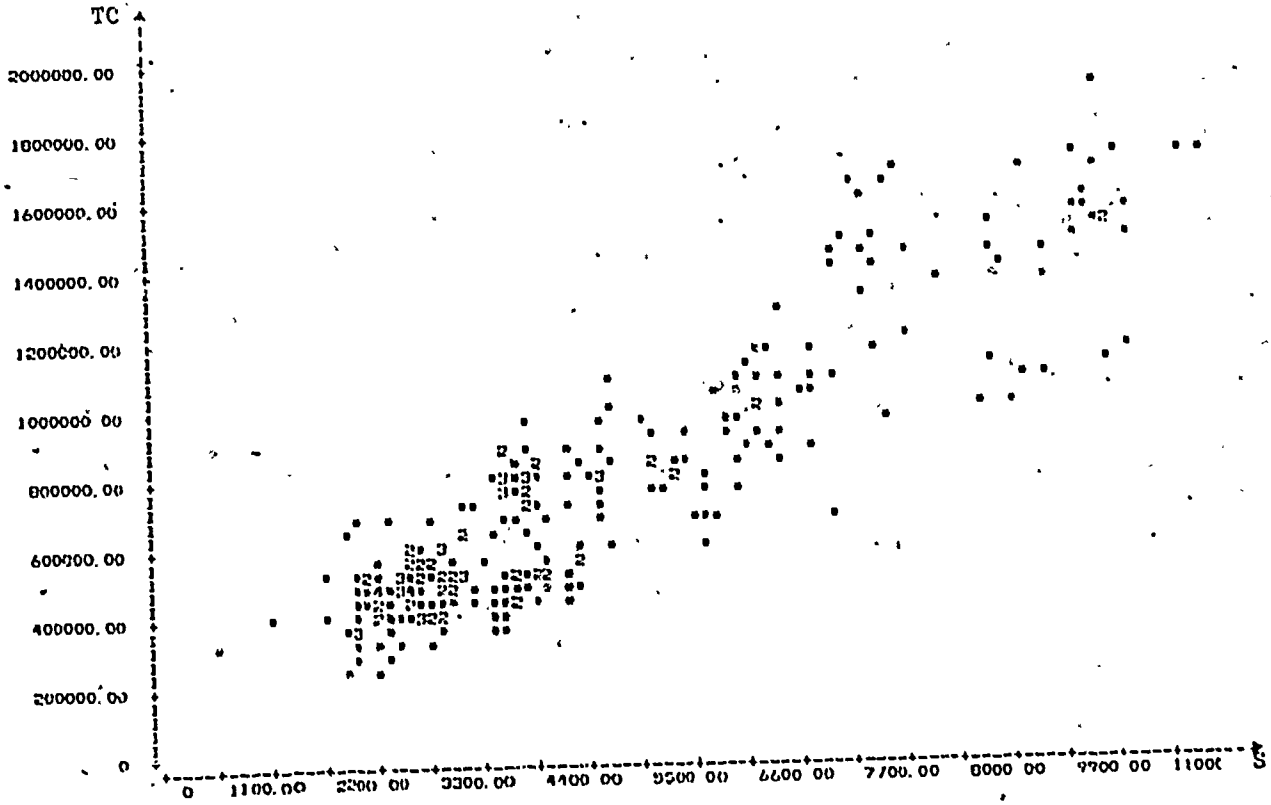

FIGURE 1. Relation between central administration expenditures and student numbers

Next we investigated the influences on the cost of the central administration program of the internal academic and external activities seperately. We estimated an administration cost function specified as follows :

$$TC = a_o + a_1 X_1 + a_2 X_2$$

The first variable X_1 represents an internal activity variable. Student numbers or academic staff positions were considered as being good parameters for internal academic activities. X_2 represents a variable which is a good index for the externally financed research output. The only measure for these activities available in the U.G.C. statistics was "total expenditures on research grants" (CR), so this variable was entered as X_2 in the cost function. Two cost functions were estimated. The regression results are shown in table 2 (regression numbers 2a and 2b). These equations give a better fit to the data points than regression numbers 1a and 1b (see increase of multiple R). In both equations the constant term (university set up cost) is very significant. The values of the regression coefficients of the internal variables S or AP became significantly smaller because of the inclusion of an external variable. The value of the coefficient of this last variable in both cost functions illustrates that every 100 pound of research grants expenditures involves extra administration cost between $\pm$ 11 and 15 pounds.

An other variable that might explain total administration costs are differences in the mix of fields of study of academic programs. More specifically we were interested in possible different administration requirements of experimental and non experimental teaching and research activities. To investigate this problem we subdivided the universities student population (S), academic staff (AP) and research grants (CR) into arts-based (α) and science-based (β) subvariables.
So we estimated two cost functions with four independent variables :

$$TC = a_o + a_1 S_\alpha + a_2 S_\beta + a_3 CR_\alpha + a_4 CR_\beta$$

$$TC = a_o + a_1 AP_\alpha + a_2 AP_\beta + a_3 CR_\alpha + a_4 CR_\beta$$

The regress on coefficient of the arts-based external research variable (CR_α) was not statistically different from zero in both equations. Moreover the standard error for CR_β was relatively large compared to the cost functions with an undifferentiated external variable. So we estimated new cost functions with a differentiated internal-activity-variable and one global external research-variable. Regression numbers 3a and 3b of table 2 show the results of the new estimation. The value of the constant term and the regression coefficient for the external research variable are statistically not different from the values found in regression numbers 2a and 2b. But in both equations -and that is what is of interest in this analysis - arts-oriented and science-oriented internal variables have significantly different regression coefficients. In equation number 3a the marginal cost of a science-student is about the double (2.1) of the marginal cost of an arts-student. The differences with respect to the marginal cost of academic staff variables are less (1.6). These differences can be easily explained. As we know students and academic staff are activity parameters for internal financed teaching and research. The needs for resources like non-academic-staff, operating funds, buildings, ...) per student or per faculty position is much higher in experimental sciences than in human sciences so that an extension in experimental academic programs will result in a larger growth of resources compared to a similar expension in non-experimental academic programs. As the volume of resources needed for academic activities affects significantly resource-related central administration programs (like personnel and finance administration) extension in both categories of academic activities will result in different extra administration costs.

TABLE 2. *Regressionresults : estimation of linear regression equations for central administration costs in British Universities*

Regression number	Constant	S	S_α	S_β	CR	R^2	N	F
1_a	125307 (6.01)	147.2 (35.8)	-	-	-	.82	273	$F_{1,271}=1277.8$
2_a	200148 (10.2)	89.9 (12.9)	-		.1483 (9.6)	.87	273	$F_{2,270}=899.9$
3_a	189998 (9.9)		61.4 (6.4)	127.1 (13.6)	.1515 (10.5)	.88	273	$F_{3,269}=671.16$
	Constant	AP	AP	AP	CR			
1_b	178683 (10.5)	1192 (41.1)	-	-	-	.86	273	$F_{1,271}=1692.9$
2_b	220533 (13.4)	831.4 (15.2)	-	-	.1153 (7.5)	.89	273	$F_{2,270}=1046.9$
3_b	214600 (12.6)	-	657.8 (6.7)	1020.5 (13.9)	.1198 (8.1)	.89	273	$F_{3,269}=732.3$

(1) t-values of coefficients are shown in Brackets

3.2.2. Testing for non constancy of marginal costs

Of all equations regression numbers 3a and 3b of table 2 provided us with the most detailed information concerning those variables that determine significantly the cost of central administration. As these relations are of the linear form marginal costs of the intervening independent variables are constant. Now the hypothesis of constancy will be tested by adding to the linear term of each variable a quadratic and a cubic term. The coefficients of the new cost function are estimated using once again the regression technique.

The cost function to be estimated is specified as :

$$TC = a_o + a_1 S_\alpha + a_2 S_\alpha^2 + a_3 S_\alpha^3 + a_4 S_\beta + a_5 S_\beta^2 + a_6 S_\beta^3 + a_7 CR + a_8 CR^2 + a_9 CR^3$$

An analogous equation can be specified with academic staff (AP) as internal activity parameter

A first estimation of the a_i coefficients resulted in higher power coefficients for the external research variable which were statistically not different from zero. This proves that the marginal cost of the research grants variable is constant. So we reestimated a new cost function with only a linear term for the external research variable. Except for the regression-coefficient of S_β all coefficients were significant at the 5 % level. The results of the last estimation of a function without S_β are listed in table 3. (see regression number 6a).

The constant term is still significant although its value decreases. Also the coefficient of the external research variable keeps the same value as found in the linear equations (between .12 and .15). As the coefficients of the cubic and quadratic terms are statistically significant marginal costs of α- and β-variables are non-constant. The marginal cost of a variable is calculated by taking the partial derivative of the total cost function with respect to that variable. The marginal

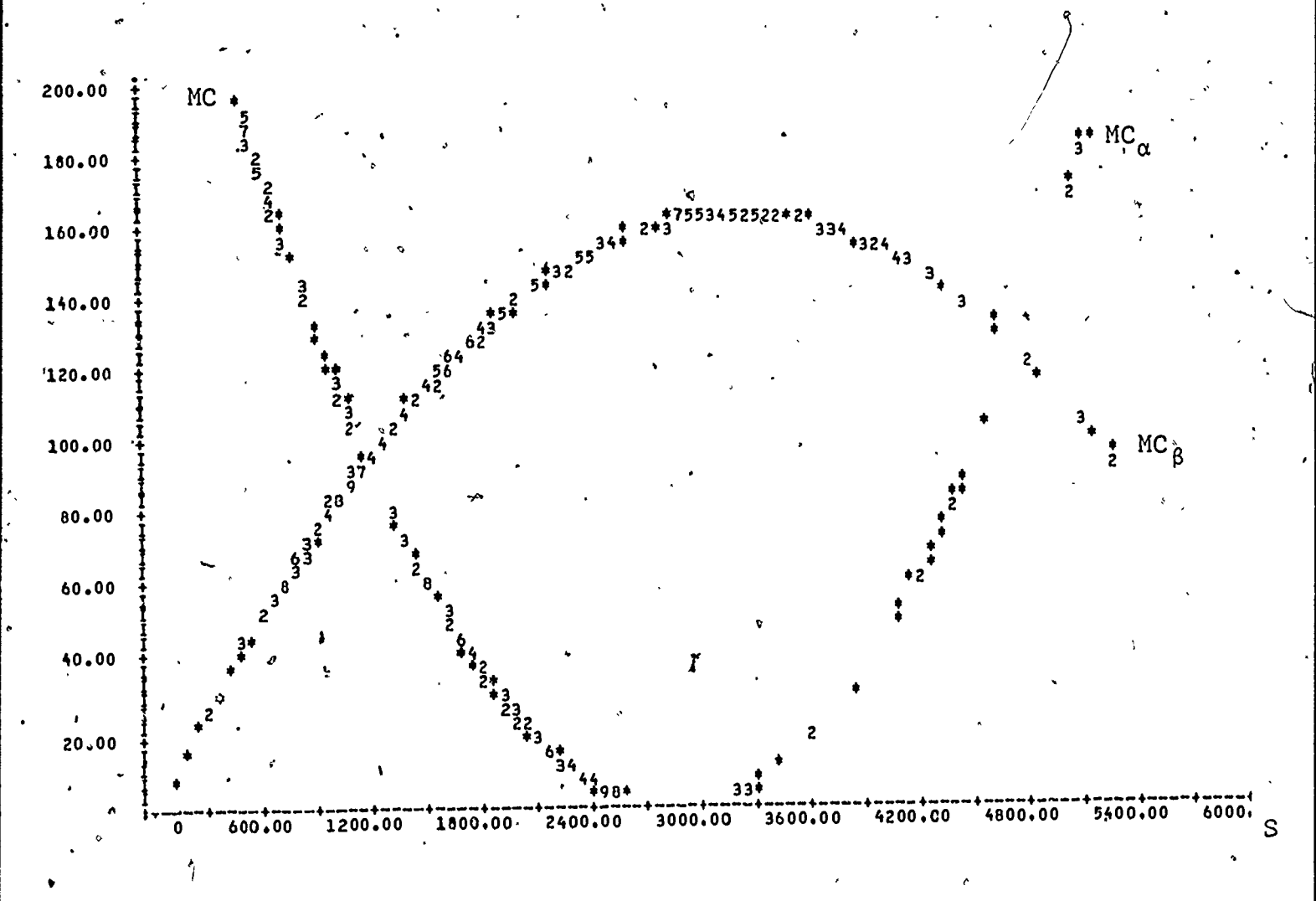

FIGURE 2. *Evolution of marginal costs of α- and β students*

TABLE 3. *Regression results : estimation of cubic cost functions for central administration in British universities*

Nr.	Constant	S_α	S_β	S_α^2	S^2	S_β^2	S_α^3	S^3	S_β^3	CR	R^2	F
4a	347.555				.0278			-1.548×10^{-6}			.83	$F_{2,270}=654.7$
	(16.3)				(12.7)			(7.0)				
5a	341.232				.0167			$-.898\times10^{-6}$		.1440	.87	$F_{3,269}=596.6$
	(18.3)				(7.3)			(4.4)		(9.1)		
6a	142 974	291		-.1033	.0527		$.122\times10^{-4}$		$-.543\times10^{-5}$	.1479	.89	$F_{6,266}=361.2$
	(2.8)	(3.9)		(3.1)	(7.1)		(2.3)		(3.6)	(10.0)		

	Constant	AP_α	AP	AP_β	AP_α^2	AP^2	AP_β^2	AP_α^3	AP^3	AP_β^3	CR
4b	367.297					2.103			$-.1056\times10^{-2}$		.87	$F_{2,270}=872.2$
	(22.0)					(16.8)			(10.3)			
5b	351 921					1.520			$-.0771\times10^{-2}$		.1084	.89 $F_{3,269}=696.1$
	(22.6)					(10.6)			(7.4)		(6.9)	
6b	147 312	2980			-11.27		4.311	.0154		$-.460\times10^{-2}$	.1177	.90 $F_{6,266}=410.6$
	(3.4)	(4.6)			(3.8)		(11.5)	(4.1)			(8.3)	

N (=number of observations) = 273
t-values of regressioncoefficients are shown in brackets

cost function for both α and β internal activity variables are illustrated diagrammatically in figure 2. As one can see the shape of the two functions is totally different. For arts-based students the marginal cost function is a U-shaped curve with a minimum cost for universities having student numbers between 2400 and 3600 students. The marginal cost in science-disciplines first raises with growth in studentnumbers and reaches a maximum value at size of ± 3200 students. Further growth will involve lower marginal costs.

As the cost functions were derived from a sample of universities with student numbers not exceeding 11000 students(respectively 5500 students for S_α and S_β) results are only relevant for universities with a size below these limits. Application of the cost function to larger universities will lead to unacceptable results. So it is not very clear how administration costs evolve as a result of further growth above the limits.

An analogous cubic cost function with academic staff as internal variable was estimated (results see regression number 6b of table 3)

4. *TESTING THE SUITABILITY OF THE BRITISH EQUATIONS TO BELGIAN UNIVERSITIES*

In this section we will explain the procedure followed in developping a set of cost equations appropriate for a Belgian University (in this case our own institution V.U.B.) and which apply th same basic variables found significant in the regression equations developped for British Universities. The suitability of last equations to Belgian universities is investigated by comparing the coefficients of the corresponding independent variables of the respective cost functions.

4.1. Methodology for estimating a Belgian cost function and results

We developped a central administration cost function with

data of the V.U.B. using the fixed variable cost method that can be summarized as follows :

- classification of central administration activities into a number of relevant administration support programs ;
- separation of fixed from variable costs for each of the administrative programs ;
- allocation of variable costs to academic teaching and research programs.

4.1.1. Classification of central administration activities

A classification of central administration activities into a number of functional administration programs is necessary to simplify the separation of fixed and variable costs and to obtain self-evident cost allocation keys.

These administrative programs can on their turn be classified into the following main categories :

a) "Resource administration programs". "These programs are occasioned by the use of resources in a university in the form of academic staff and operating funds. They consist of :-personnel administration program
-financial administration program
-administrative data processing

b) "Academic activity administration programs". Teaching and research give raise to :
-instruction administration
-research administration

c) "Academic student administration program". This program is occasioned by the participation of students to academic activities. Administration work due to social student services activities are not included in this program

d) "General management program". These activities include administrative and academic leadership, planning activities,

institutional research and so on. They are a result of the overall activities in a university.

By classifying central administration activities in this way one gets very self-evident allocation keys to assign the costs of most of these programs to the final academic outputs.

4.1.2. *Separation of fixed from variable costs*

For each activity category fixed costs were seperated from variable costs. Of course the fixed or variable nature of costs can not be determined empirically, so this step is almost entirely a political and judgmental matter. In general salaries relating to administrative leadership and equipment costs were considered as fixed while wages of executive (clerical) personnel were treated as variable costs. Columns a and b from table 4 give for each administrative program the fixed and variable components.

4.1.3. *Allocation of variable costs to academic teaching and research programs*

Fixed costs were excluded from the analysis and the variable administration costs were allocated to academic teaching and research programs.

Resource administration programs give administrative support to any university program. This means that they administrate resources used for teaching and research purposes as well as resources used in academic support programs (libraries, computer centers, physical plant operations...) and that they also give administrative support to themselves. E.g. the salary and wage administration also pays the wages of staff belonging to the accounting department, purchasing office, academic staff administration. And the financial administration office also administrates budgets of academic and non-academic administration offices and of the administrative data processing department.

To take full account of these mutual support relations that exist between resource administration programs we used a cost allocation matrix (C.A.M.) for allocating the costs of these programs to a number of intermediate programs consisting of :

- the remaining categories of administration programs (academic activity administration, student administration, general management)
- resource administration programs for administration of resources used in teaching and research activities.
- resource administration programs for administration of resources used in academic support programs.

A coefficient a_{ij} of this matrix (A) represents the share of program i in the total consumption of support services provided by program j. The coefficients of the inverse matrix (I-A) allocate the direct costs of the resource administration programs to the intermediate programs. The results of this allocation are shown in column c of table 4.

The variable costs assigned to each of the intermediate administration programs were then further allocated to the academic teaching and research programs using the most appropriate allocation key for each program (see list below).

administration of instruction	teaching volume
student administration	number of students
research administration	cost of research
administration of academic staff	number of academic staff
administration of non academic staff	number of non academic staff
physical plant	number of square foot
libraries	books, periodical budget
computer center	used computer time

Finally we divided the total amount of allocated costs of each program by the value of the activity parameter relevant for that program. According to the regression equations estimated

TABLE 4. *Allocation of central administration costs to academic teaching & research programs*
FREE UNIVERSITY BRUSSELS - 1978 (in Belgian francs x 1000)

Administration program	Direct costs		total of allocated costs (c)	Allocation of costs to final academic programs		
	Fixed (a)	variable (b)		arts-teaching research (d)	science-teaching research (e)	external funded research (f)
Personnel administration	3 850	9 208				
Financial administration	5 841	19 175				
Administrative data processing	1 343	20 653				
Admin. of instruction	898	3 059	3 248	1 267	1 981	-
Student-administration	1 200	2 197	2 325	1 186	1 139	-
Research Administration	1 216	5 715	6 157	739	2 709	2 709
Top management	13 043	9 676	11 925	2 027	6 082	3 816
Resource administr. of Academic activities						
Admin. of academic staff			6 414	1 887	3,503	1 024
Admin. of non acad staff			5 134	660	3 464	1 010
Admin. of operating funds			26 755	1 946	11.028	13 781
Resource administr. of support programs						
Physical plant			4 931	937	3 994	-
Libraries			2 466	1 036	1 430	-
computer center			243	32	211	-
others			85	85	-	-
TOTALS	27 391	69 683	69 683	11.802	35 541	22 340

in table 2 for British universities we obtained six corresponding equations for the V.U.B. :

1_a $TC = 27391000 + 15112(S)$

1_b $TC = 27391000 + 139088\ (AP)$

2_a $TC = 27391000 + 10267(S) + .1111(CR)$

2_b $TC = 27391000 + 94497(AP) + .1111(CR)$

3_a $TC = 27391000 + 5009(S_\alpha) + 15760(S_\beta) + .1111(CR)$

3_b $TC = 27391000 + 71527(AP_\alpha) + 105777(AP_\beta) + .1111(CR)$

4.2. Comparison of the Belgian with the British equations

Table 5 compares the coefficients of the corresponding independent variables of the British linear regression equations with the respective Belgian cost functions. Column b of that table shows the regression coefficient of the British cost functions expressed in Belgian francs of 1977. The coefficients of the internal variables- differentiated or not into α and β -subvariables - and the constant terms of the equations estimated in table 2 were converted into Belgian currency. For this we used a conversion rate, representing the relation between unit labourcosts in Belgium and in the United Kingdom for 1977 (115 BF/£).
The regression coefficient of the external research variable (CR) can be considered as a percentage of that independent variable so that no conversion is needed here.
The parameters of the Belgian equations were also adjusted to the price level of 1977 (see column a).

Cost functions with academic staff as independent internal variable generally give better results compared to equations with number of students as activity parameter. This conclusion is consistent with the results found in the regression analysis where multiple correlation coefficients were better for the first category of equations. In fact for equation numbers 1b, 2b, and 3b the constant terms and the external-research coefficients of the regression equations and the Belgian cost functions are of the same size, where as differences between thesecoefficients in the corresponding "student-equations" (1a,2a and 3a) are much bigger.

TABLE 5. *Values of the coefficients of British linear regression equations and Belgian cost functions expressed in Belgian francs of 1977*

Equation number	Parameter	VALUES IN	
		Belgian cost-functions (a)	British regression equations (b)
1a	constant	26 216.000	14 410 000
	S	14 464	16 933
1b	constant	26 216 000	20 549 000
	AP	133 121	137.103
2a	constant	26 216 000	23 017 000
	S	9 827	10.343
	CR	.1111	.1483
2b	constant	26 216 000	25 361 000
	AP	90-443	95 605
	CR	.1111	.1153
3a	constant	26 216 000	21 850 000
	S_α	4 794	7 064
	S_β	15 085	14 621
	CR	.1111	.1515
3b	constant	26 216 000	24 679 000
	AP_α	68 459	75 644
	AP_β	101 239	117 353
	CR	.1111	.1198

In both kind of cost functions science students or academic staff require more central administration expenditures than arts students or faculty. However, the difference between cost deviations is more important in "student equations" (3a) than in "faculty equations"(3b) Cost differences between α and β academic staff are in last category of equations nearly the same in British as in Belgian cost functions (about 70%).

Testing the suitability of the non linear regression equations was not possible because the Belgian cost function refers to one year only (1978). The estimation of parameters for several years seemed impossible because of the lack of enough detailed data.

5. CONCLUSIONS

One overall conclusion that can be drawn from this study is that resources needed for the central administration program in a university are related to student numbers in a more indirect way than a more proportionality.

First a significant part of total costs is fixed and do not depend on any activity parameter. This fixed cost component may be interpreted as the setting-up cost of a university administration prior to the first admission of students. These fixed costs consist mainly of salary expenditures for the leadership function of the different administration programs.

Secondly other variables than only student number influence the central administration reguirements. This is true for the granted research activities and for the mix of fields of studies in a university. Granted research activities involve higher administration expenditures than teaching and teaching-related-research activities. So we found in the cost analysis for the Belgian university that administration cost as a percentage of academic expenditures amounted to about 11% for granted research activities versus 6% for university funded activities.

Experimental academic activities (represented by number of students or academic staff) require a more expensive central administration than non experimental activities. But cost differences per student or faculty member are mainly the result of higher requirements of academic resources for the first category of activities.

Finally we found that marginal costs with respect to internal activity parameters are non-constant. The shape of the marginal cost function for α-disciplines is of a U-shaped form with minimum costs at a size of about 3000 students. For experimental activities the marginal cost function implies that small or large universities bear the brunt of expansion and those in the medium range have the highest marginal costs. Due to the composition of the data sample results are only relevant for universities with a size below 11000 students.

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