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Cost structure, economies of capacity utilization and scope in Swiss higher education institutions

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COST STRUCTURE, ECONOMIES OF CAPACITY UTILIZATION AND SCOPE IN SWISS HIGHER EDUCATION INSTITUTIONS

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1 Introduction

In today's economic and financial environment, the issue of costs and cost structures of higher education institutions (HEIs) is becoming increasingly sensitive even in countries like Switzerland, where traditionally universities have been relatively well funded with respect to the number of students.

The issue leads to a set of different questions. A first question concerns allocative and cost efficiency, i.e. the extent to which an institution is able to minimize the level of inputs or the total cost of inputs for a given level of output (Salerno 2004). A second one concerns scale efficiency, i.e. the extent to which institutions operate at an optimal size. A third question concerns the existence of economies of scope through the joint production of different types of outputs – notably education and research – or, for education, the joint offer of curricula in different domains (Bonaccorsi and Daraio this volume).

A further issue concerns the reasons for the large differences in cost levels per student in different domains shown by all studies where disaggregated data are available (see Jongbloed and Salerno 2004 for the Dutch case): in principle these differences could be explained by intrinsic differences in the production of educational outputs or by different mixes of outputs – for example research intensity being larger in some domains – or by inefficient allocation of resources inside a university.

There is an impressive body of literature on these issues, but very few general results are applicable. For instance, most efficiency studies suggest that technical and/or cost efficiency of higher education is relatively high (Salerno 2004), but the validity of these results is largely impaired by methodological problems concerning the techniques adopted, the indicators used (for instance, difficulty in measuring the quality of outputs) and the homogeneity of the sample (different subject mixes and missions of HEIs). In addition, the evidence concerning returns to scale in higher education and trade-offs between education, research and the third mission is ambiguous at the least (Bonaccorsi and Daraio this volume). Analyses at the discipline level are even more difficult since disaggregated data of reasonable quality are available only for small countries such as the Netherlands, Switzerland and Norway, where the limited numbers of observations represent severe limits to the analysis.

In this paper we propose an analysis of the cost structure of Swiss higher education institutions. We address this issue in two stages: First, based on the available data we propose some simple indicators of cost, activities and performance. By simple indicators we mean the ratio-type measures whose estimation does not require any mathematical or statistical analysis. These indicators have several limitations due to the fact that they do not capture the differences between universities' characteristics with regards to both outputs and operating conditions. However, simple indicators can be useful in understanding the variation patterns of different factors among higher education institutions and between different domains[1]

In the second stage, the cost structure of the Swiss universities will be studied using more elaborate statistical methods. We focus on the econometric estimation of a cost function. One advantage of this approach is that it takes into account not only the observed differences among universities through explanatory variables, but also part of the unobserved random variations.[2] Both economies of capacity utilization and economies of scope will be studied. From a policy point of view it is important to identify to what extent universities actually exploit the potential economies of capacity utilization and economies of scope and if there is any possible improvement in this regard. Moreover, the empirical results obtained from the estimation of a cost function may used in the mechanism for providing funding, to evaluate new ways of reimbursing institutions, and can be useful in evaluating pricing policy for domestic as well as for overseas students.

Finally, the analysis performed here is of the highest political interest in the context of Swiss higher education policy. Namely, the system of governance and funding of higher education is extremely complex and fragmented (see Lepori this volume), but recently a proposal has been put forward to switch to a new funding system based on standard costs for education and on overheads on competitive grants for research (Groupe de projet «Paysage des Hautes Ecoles 2008» 2004). Since standard costs will be based on the actual situation, it is crucial to assess the extent to which today's differences in average costs are intrinsic to production structures – for example higher costs in natural sciences and in medicine due to laboratory and practice periods – and to differences in the level of research and teaching activities, or if they are the result of internal allocation which favored some

[1] For a discussion on the difference between simple and econometric based performance indicators see Farsi and Filippini (2006).

[2] For a discussion of the possibility of using panel data in order to consider unobserved heterogeneity among firms in the estimation of cost functions, see Farsi et al. (2005b).

domains and, for example, allowed some domains to fund research to a larger extent through the university's general budget. Failure to assess this could result in an ineffective and inefficient funding system.

The paper is organized as follows. In section 2, we briefly present our sample and the available data. In section 3, we produce a set of indicators to characterize Swiss higher education institutions, and we perform a cross-analysis between institutions and main disciplinary groups. Then, in section 4, we apply an econometric approach to estimate marginal costs of education and to verify the existence of scale and scope effects in educational production. Finally, the last section proposes some interpretations of the results as well as methodological implications for the field of study.

2 The sample and the available data

Our sample is composed of the ten Swiss cantonal universities and the two Federal Institutes of Technology (FITs; see Table 1). The two FITs are directly regulated and completely financed by the the Swiss federal government, while the cantonal universities are under the sovereignty of their home Canton and are co-funded by the Confederation and by the other university cantons. These differences in the legal and financial framework have to be considered as possible explanations for cost differences between institutions (see Lepori, this volume, for more details). We exclude the seven universities of applied sciences, since they differ considerably in the structure of the curricula as well as in their activities (a lower R&D activity share).

Name	Acronym	Foundation	Under-graduate students	Humanities and Social Sciences	Natural Sciences	Technical Sciences	Medicine
University of Basel	UNIBS	1460	6,307	X	X		Y
University of Bern	UNIBE	1528	10,219	X	X		X
Federal Institute of Technology Zurich	ETHZ	1854	4,465		X	X	
Federal Institute of Technology Lausanne	EPFL	1968	9,275		X	X	
University of Fribourg	UNIFR	1889	8,634	X	X		Y
University of Geneva	UNIGE	1559	10,132	X	X		X
University of Lausanne	UNIL	1537	7,851	X	X		X
University of Lugano	UNISI	1996	,481	X		X	
University of Luzern	UNILU	1574	536	X			
University of Neuchâtel	UNINE	1838	2,598	X	X		
University of Sankt Gallen	UNISG	1898	4,104	X			
University of Zurich	UNIZH	1833	19,104	X	X		X

Table 1. Basic data on higher education institutions (2002)

Y: only part of the curriculum

We notice major differences concerning the subject mix of these universities. The two FITs cover only natural sciences and technical sciences, while a full curriculum in medicine is present only at the largest cantonal universities (Basel, Bern, Lausanne, Geneva and Zurich). These differences are relevant since we will show later that average costs per student differ greatly according to the scientific domain.

Most of the data used in this chapter are taken from the Swiss University Information System (SIUS), a database managed by the Swiss Federal Statistical Office (SFSO) containing information on finances, staff, students and degrees of Swiss universities. All data are available in the yearly publications of the SFSO (for more details, see Lepori 2005). Data considered here cover the following domains (see the Annex for full details):

- Education: number of undergraduate students (this includes bachelor and (Bologna) master's degrees; see the Annex) and number of PhD students. Number of undergraduate degrees and PhD degrees.
- Staff in Full Time Equivalent divided in three categories: professors; other academic staff; technical and administrative staff.
- Expenditures divided between personnel (divided by personnel category) and operating expenditures. Investments and capital costs are not generally included since in most cases buildings are owned by the state, and investment costs are financed directly by the state budget. We notice that for the "practice years" in clinical medicine, the separation between higher education and healthcare costs is quite problematic, and this could have a major impact on some indicators since the corresponding amounts are very large.
- Capital stock. There are some estimates of the total floor space available, which we use as a proxy for the capital stock.
- ISI Publications.

All data are disaggregated by university and by activity domain; SIUS provides a very detailed breakdown according to a list of 81 activity domains, which are then grouped in seven main disciplinary groups (Humanities and Social Sciences; Economics; Law; Exact and natural sciences; Medicine and Pharmacology; Technical Sciences; Interdisciplinary and other) plus a central domain for central personnel and expenditures which cannot be divided. These activity domains do not correspond to organizational units, but are formed by grouping departments and research institutes according to their main activity domain.

For this analysis, we regroup the domains by including economics and law in humanities and social sciences for a total of four domains[3]. This division is similar to that used by Jongbloed and Salerno (2004) using three disciplinary clusters (humanities and social sciences; medicine; natural and

[3] The interdisciplinary domain, is very small and therefore is not considered.

technical sciences); the separation of technical sciences is justified since these are present only the two Federal Institutes of Technology.

The time coverage for these data is 1994-2003 except for publication data, where five-year means from 1981-1986 to 1997-2001 are available and were approximated to yearly values. All monetary values have been converted in 2000 Swiss Francs (CHF), adjusted for inflation using GDP deflator series.

3 Costs and cost structures

In this section, we produce and analyze a set of indicators on the production and cost structure of Swiss universities. First, we consider the universities as a whole; then we perform an analysis for the activity domains across all Swiss universities. Finally we compare more in detail selected activity domains of all universities. In this part of the analysis we do not explicitly consider any measure of productivity or efficiency because it would be necessary to define relevant measures of outputs and inputs; rather, we focus on differences between universities and domains[4].

3.1 The selection of the indicators

The indicators chosen here cover costs, education output and quality, research output and capital stock available for production.

a) *Cost indicator.* We consider here the total operating costs of the university divided by the number of students (*average costs per undergraduate student*). We notice that in this analysis, we consider jointly costs/staff incurred for all university activities, including education, research and services. The main reason for this choice is that Swiss universities do not have an analytical accounting system that distinguishes between different activities; the share of education and research expenditures is based on a yearly survey of time use by personnel using the Frascati manual (OECD 2002) methodology. However, the quality of these data has to be questioned: firstly, some studies indicate that the reliability of a time survey might be low due to different individual definitions of activities (Teichler 1996); moreover, there are a number of methodological issues concerning the division of general costs between research

[4] We note that the productivity analysis of the Swiss higher education institutions is beyond the goals of this paper. Moreover, in order to construct any measure of productivity, one needs to define relevant measures of outputs and inputs. In the case of the Swiss universities the lack of information on the research performance creates some problems in doing a productivity analysis.

and education (Jongbloed and Salerno 2004). For this reason, we prefer to control for research intensity using other indicators[5].

b) *Teaching output and quality*. As in most higher education efficiency studies, we use the number of undergraduate students to measure the level of education output since using the number of degrees has some methodological problems (for example, time lag; Salerno 2004). For measuring quality, the simplest indicator is the number of students per professor.

c) *Structure of personnel.* We adopt the number of academic staff per professor as the main indicator of the structure of personnel.

d) *Research intensity.* In the literature, some indicators are discussed to measure research intensity (see Slipersaeter 2005 for a review). The simplest, which is the main criterion used in the Carnegie classification of the US universities, is the number of PhD degrees awarded per 100 undergraduate students. Scientific publications from ISI are also regularly used, but with the main drawback of not covering adequately humanities and social sciences (Hicks 2004). An alternative indicator which has been used in many studies is the share of third-party funds and especially competitive research grants. Its main drawback in this context is, however, that it is highly dependent on the subject mix since competitive funds are distributed quite unevenly according to disciplines.

e) *Capital stock*. As already explained, the floor surface is the only indicator available which is more or less comparable across the sample. We normalize it for undergraduate student and for staff.

3.2 University-level analysis

Table 2 presents the basic indicators for the 12 Swiss universities and FITs considering the higher education institutions as a whole. Some results are very evident.

1) Firstly, the differences in the average cost per undergraduate student are very large, since the highest value (EPFL) is about five times the lowest value (University of Fribourg). Moreover, the two FITs have higher average costs per student than cantonal universities; however, even average costs for cantonal universities differ by a factor of two.

2) Secondly, research intensity and output indicators also show considerable differences. Thus, even excluding the two smallest universities (Lugano and Luzern), the number of PhD degrees per 100 undergraduate students varies between 6.7 for the ETHZ and 1.5 for the University of Fribourg. We notice that these values are quite high in an international comparison (Jonbgbloed, Lepori, Salerno and Slipersaeter 2005). ISI Publications per student show also some variations, but we have to consider that the lowest values concern universities with a very high share of the humanities and social

[5] The data from the new analytical accounting system of the Swiss universities could lead to improvements especially concerning the breakdown between education and research expenditures; initial data for 2004 have been recently published (Conférence Universitaire Suisse 2006).

sciences. In the Swiss case, the humanities and social sciences account for only 4% of the total ISI publications (CEST 2003).

3) Staff indicators show also considerable variations: the number of students per professor varies from 24 in Basel to 59 in Sankt Gallen, and the indicators for the whole staff show roughly the same pattern. At the same time, average labor prices show a limited variation across the sample.

4) Finally, capital stock varies also strongly according to the university, but differences are rather limited if we consider the square meters per staff. The value for Luzern should be considered with care since data are from 1999 and the university expanded considerably in the last few years.

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	Undergraduate students	Costs per undg student	sqm per undg student	sqm. per staff	PhD degrees per 100 undg. students	Undg. Students per professor	PhD students per professor	Academic staff per professor	Avg. Labour price	Publications per 100 undg. students
Bern	10,219	51,537	10.2	32.8	5.1	38	5	6	100,373	16
Basel	6,307	50,949	24.9	73.1	6.4	24	6	5	102,708	22
EPFL	4,465	104,283	35.9	54.3	5.1	26	5	11	115,410	22
ETHZ	9,275	99,229	35.9	52.8	6.7	27	7	12	102,189	25
Fribourg	8,634	22,082	7.1	41.8	1.5	40	4	4	94,933	3
Geneva	10,132	59,313	13.7	39.0	3.0	30	4	5	115,772	20
Lausanne	7,851	43,745	14.5	57.3	2.6	25	5	4	117,156	19
Luzern	536	34,031	3.8	20.4	0.4	21	3	2	147,278	NA
Neuchâtel	2,598	45,644	15.1	49.5	3.7	23	4	4	112'973	9
Sankt Gallen	4,104	31,301	6.8	42.4	3.1	59	12	5	139,420	NA
Lugano	1,481	28,064	5.3	35.6	0.3	38	2	3	114,944	NA
Zurich	19,104	44,009	11.3	44.4	3.7	54	9	8	110,214	13
Mean	7,059	51,182	15	45	3	34	6	6	114,448	7,059
STDEV	5,064	25,942	11	13	2	12	3	3	15,371	5,064
Median	7,079	44,826	12	43	3	29	5	5	113,959	7,079

Table 2. Basic data and indicators for Swiss universities (2002)

All data in CHF at prices of 2000.

Square meters: data at 1999

3.3 The importance of the subject mix

We now examine the extent to which differences in average costs are linked to different subject mixes, and in particular to the specialization in natural and technical sciences of the two FITs, as well as to the presence of a faculty of medicine in some cantonal universities. As a first approach, Table 3 shows the average cost per student by university and disciplinary group.

	HUM & SOC	NAT	MED	TEC	All
Bern	14,142	82,754	199,491		51,537
Basel	19,852	164,487	76,421		50,949
EPFL		139,302		87,657	104,283
ETHZ		101,340	59,082	91,191	99,229
Fribourg	15,165	77,291	79,260		22,082
Geneva	21,886	212,023	246,017	144,808	59,313
Lausanne	17,299	109,162	136,243		43,745
Luzern	34,031				34,031
Neuchâtel	18,577	141,457		421,574	45,644
Sankt Gallen	31,301				31,301
Lugano	15,370			53,893	28,064
Zurich	13,427	109,333	221,058		44,009
Mean	20,105	126,350	145,367	159,825	51,182
STDEV	7,147	42,878	76,856	149,898	25,942

Table 3. Expenditures per undergraduate student by university and disciplinary group, 2002

In interpreting this table, we need to take into account some specific features which alter comparability of results:

- In medicine, Fribourg and Neuchâtel do not offer a full curriculum and, in particular, do not offer the last years which are more cost-intensive due to the “practice period”. In addition, the ETHZ offers pharmacology only, while for Basel, medicine costs are underestimated since not all contributions to the cantonal hospitals are included in university expenditures.
- In technical sciences, Lugano offers only a curriculum in architecture with a strong orientation towards the humanities and social sciences and thus cannot be compared with the FIT; in addition, the technical science program in Neuchâtel is very small with only 38 students.

We notice that differences in average costs when comparing groups of disciplines are very large, but that the differences in average costs when comparing universities in the same disciplinary group are lower. This is especially apparent in the two domains where we have many observations, namely the humanities and social sciences, and natural sciences. This analysis significantly modifies the position of the two FITs: in natural sciences, where we can compare them with cantonal universities, the ETHZ and EPFL have costs which are similar to cantonal universities in the corresponding domains. It is only by averaging natural sciences with the humanities and social sciences that lower aggregate values are obtained by cantonal universities.

3.4 Personnel and cost structure by discipline

The following two figures show also very significant differences concerning the staff structure and cost structure by the main disciplinary groups. The most striking difference concerns the share of professors as a part of staff and as a part of costs: they account for 15% of FTE and 22% of total costs in the humanities and social sciences, while in the other domains they account for slightly more than 5% of FTE and about 10% of the total costs (5% of the costs in medicine). As expected, operating expenditures are much higher in the natural and technical sciences and in medicine, where they comprise a large part of the reimbursement paid by the university to the hospitals for training and research.

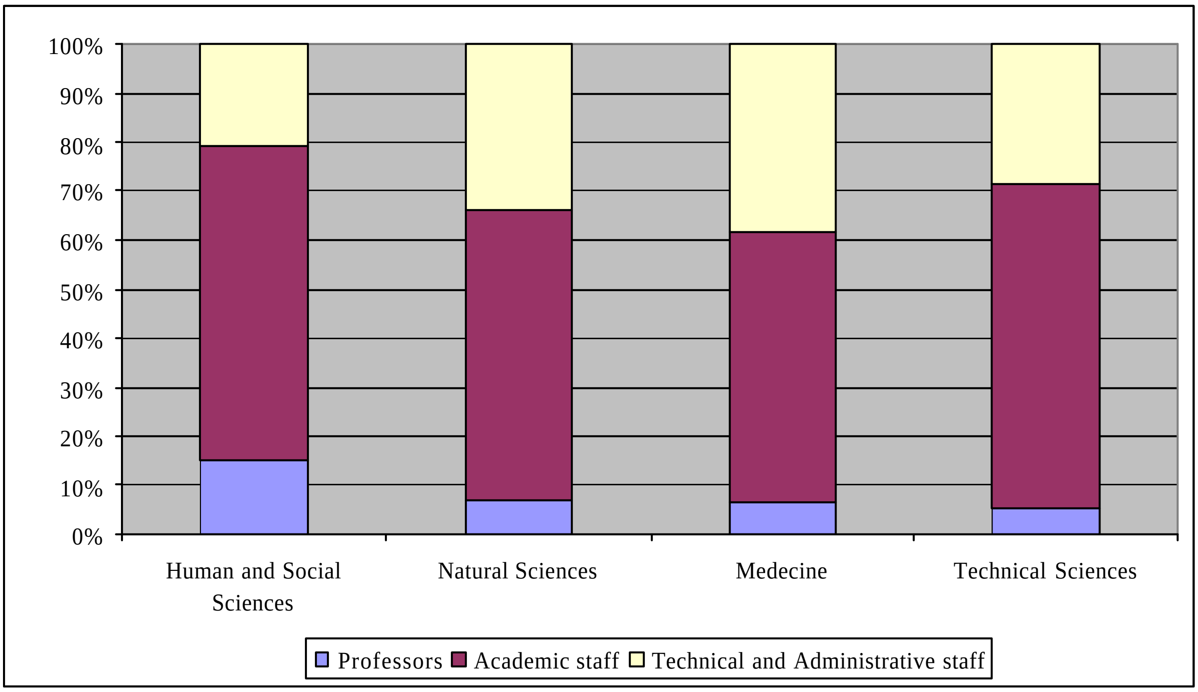

Figure 1. Structure of the staff by main disciplinary groups (FTE, 2002)

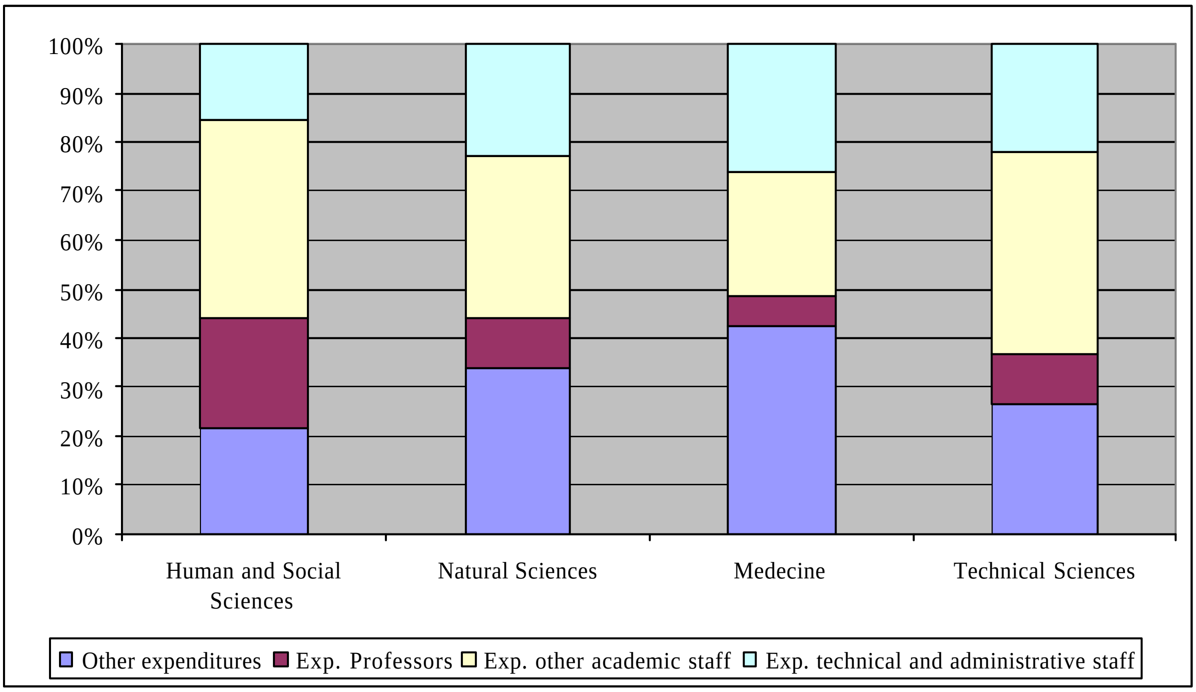

Figure 2. Structure of expenditures by main disciplinary groups (2002)

3.5 A detailed analysis of the different disciplinary groups

Table 4 presents the basic cost indicators for each university for the four main disciplinary groups used in this analysis, which lead to the following remarks.

a) *Humanities and Social Sciences*. We notice two outliers concerning average costs which can readily be explained by their different composition of curricula. The first one, Sankt Gallen, is essentially a business school, and most of the students are concentrated in economics. The second one, Lucerne, besides being the smallest in the sample, covers only theology, the humanities and law and thus lacks domains with a high number of students in social sciences. Correspondingly, the average number of students per professor is much lower than in other universities. Excluding these two cases, the standard deviation in the average cost per students is only about 20%, and most other indicators also show limited variation.

The figure 3 plots the main indicators according to the number of undergraduate students. We notice that average costs show a rather limited tendency to decrease with increasing size. The trends for the other indicators are much clearer. So enrolment ratios increase quite strongly from 20-30 students per professors in the smallest universities, to 40-50 in the middle group to above 80 for Zurich. At the same time, the number of academic staff for each professor also increases noticeably; and since a significant share of academic staff is composed of PhD students, the number of PhD degree per undergraduate student also shows an increasing trend. We will come back to interpreting the meaning of these results in the last section, in the light of the econometric analysis.

	Undg. students	Costs per undg student	sqm per undg student	sqm. per staff	PhD degrees per 100 undg. stud.	Undg. Students per prof.	PhD students per prof.	Academic staff per prof,	Avg. Labour price
Humanities - Social Sciences									
Bern	7,176	14,142	5.0	42.3	0.8	67	5	6	105'192
Basel	4,273	19,852	10.6	90.3	1.9	47	7	4	133'625
Fribourg	7,681	15,165	4.1	34.5	0.7	51	5	4	96'975
Geneva	8,283	21,886	5.2	36.9	1.0	46	4	4	127'023
Lausanne	5'950	17,299	7.3	54.3	0.4	41	5	4	113'678
Luzern	536	34,031	3.8	20.4	0.4	21	3	2	147'278
Neuchâtel	2,113	18,577	5.6	44.9	1.1	32	4	2	128'257
Sankt Gallen	4,104	31,301	6.8	42.4	3.1	59	12	5	139'420
Lugano	993	15,370	3.9	40.4	0.5	34	3	2	113'373
Zurich	15,405	13,427	3.9	44.1	1.4	83	9	5	109'873
Mean	5,651	20,105	5.6	45.0	1.1	48	6	4	121'469
STDEV	4,388	7,147	2.1	18.1	0.8	18	3	1	16'120
Natural Sciences									
Bern	1,559	82,754	30.2	50.9	12.5	23	6	8	103'931
Basel	921	164,487	54.9	46.9	16.4	13	8	9	90'691
EPFL	1,404	139,302	38.4	46.3	7.3	21	5	11	113'004
ETHZ	4,195	101,340	30.5	44.7	9.9	25	8	11	100'194
Fribourg	691	77,291	34.7	59.3	11.1	14	4	4	88'778
Geneva	861	212,023	60.3	48.8	15.3	12	6	7	108'922
Lausanne	682	109,162	70.1	95.4	16.6	15	9	6	106'744
Neuchâtel	447	141,457	51.3	52.6	14.8	11	5	7	104'440
Zurich	1,645	109,333	45.9	72.9	9.4	25	9	10	98'872
Mean	1,378	126,350	46	58	13	18	7	8	101'731
STDEV	1,137	42,878	14	17	3	6	2	2	8'033
Medicine									
Bern	1,485	199,491	14.3	15.2	18.3	15	5	6	95'115
Basel	1,113	76,421	54.6	108.0	15.6	11	5	2	98'058
ETHZ	325	59,082	18.9	52.4	6.8	45	14	11	105'960
Fribourg	262	79,260	22.6	40.2	0.0	18	0	3	99'056
Geneva	929	246,017	42.5	31.0	8.8	12	4	7	110'918
Lausanne	1,219	136,243	18.9	33.3	5.5	10	4	3	128'698
Zurich	2,054	221,058	39.1	32.6	16.4	19	8	12	115'163
Mean	1,055	145,367	30	45	10	19	6	6	107'567
STDEV	631	76,856	15	30	7	12	4	4	11'804
Technical Sciences									
EPFL	3,061	87,657	34.6	59.8	4.1	29	5	11	116'991
ETHZ	4,755	91,191	40.3	62.2	3.8	32	7	14	101'973
Lugano	488	53,893	8.2	32.0	0.0	50	0	7	116'140
Mean	1,680	159,825	55	57	6	26	5	9	113'809
STDEV	2,128	149,898	43	19	8	17	4	4	8'303
Median	488	91,191	40	60	4	29	5	11	116'140

Table 4. Indicators for the main disciplinary groups, year 2002

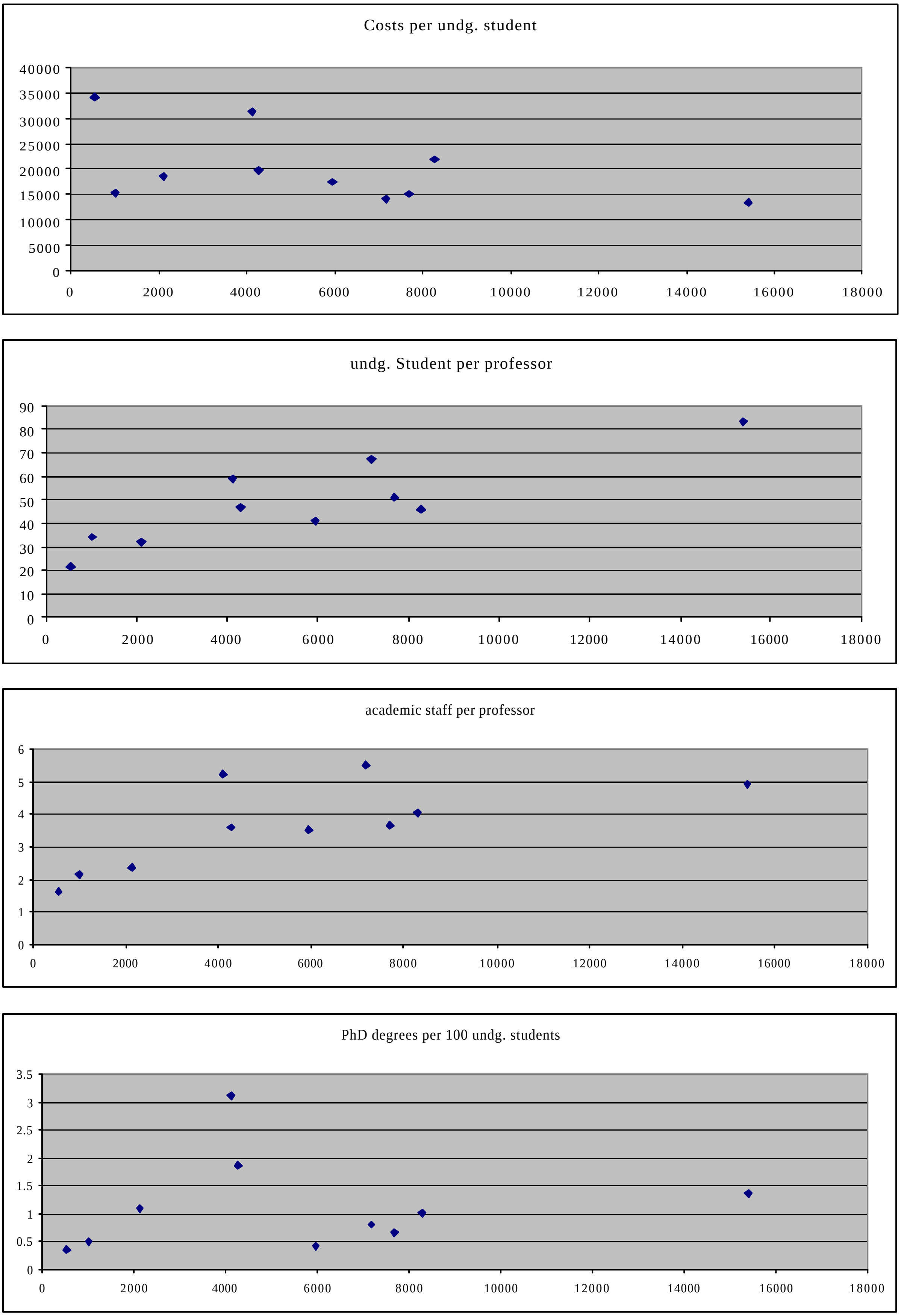

Figure 3. Main indicators by number of students, humanities and social sciences

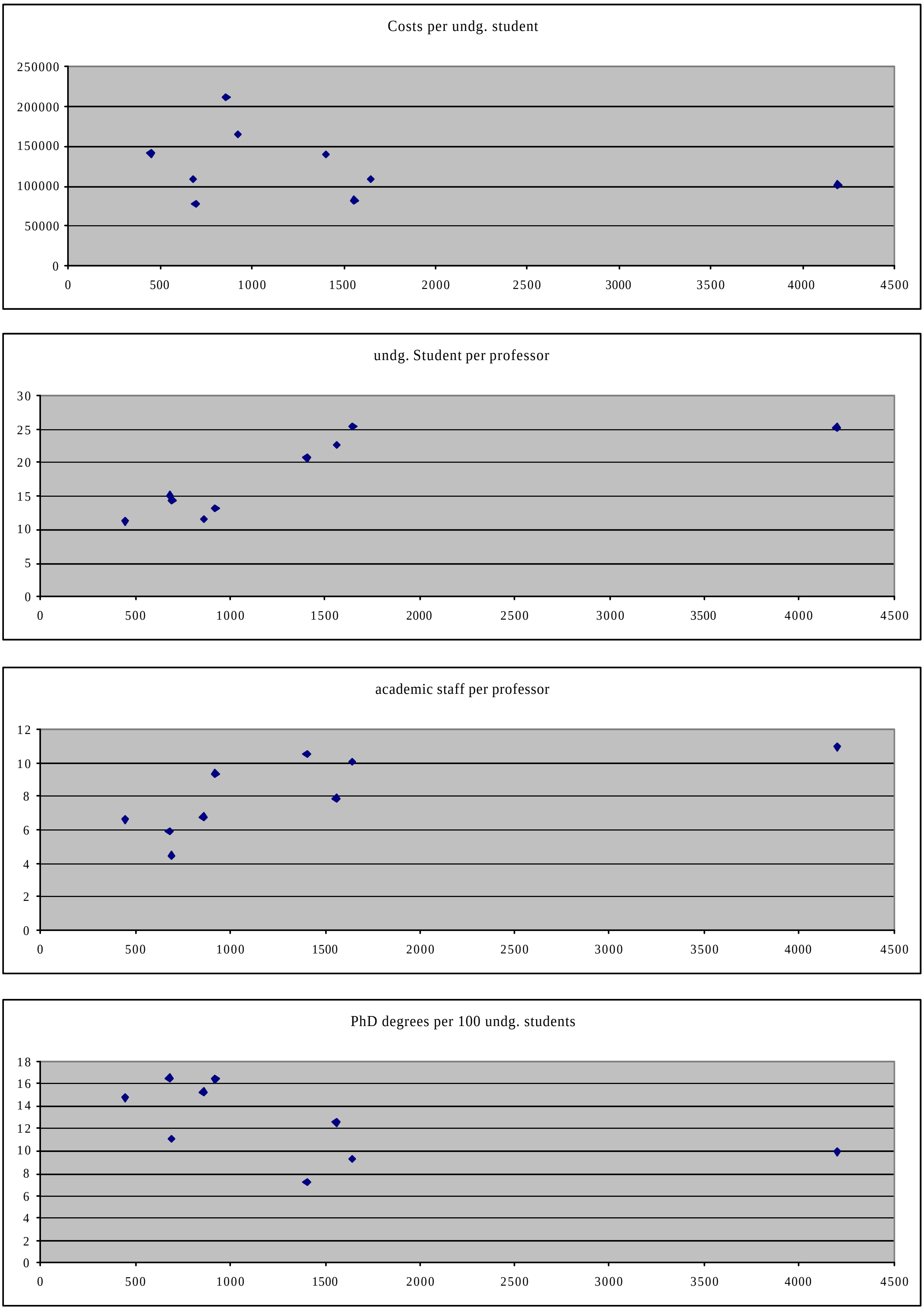

Figure 4. Main indicators by number of students, natural sciences

b) *Natural sciences*. We notice immediately that the number of students is much lower, and the variation between the largest and the smallest university is smaller than in the humanities and social sciences if we exclude the ETHZ Zurich, which is much larger than all other universities in this domain. Again, a discernible trend is the increase in the number of students per professor and the corresponding increase in the number of non-professor academic staff in relation to the number of students. However, the number of students per professor is much lower than in the humanities and social sciences for the whole range of university size. However, costs per undergraduate students and PhD degrees do not show clear trends in relation to university size.

c) *Medicine*. A reasonable comparison is only possible between Bern, Geneva, Lausanne and Zurich. Fribourg does not offer a complete curriculum, while the ETHZ offers pharmacology only. The low value for Basel is a statistical artifact since the data contain only the cost of preclinical training, while the costs of training in hospitals is paid directly by the Canton; taking this into consideration would more then double the total costs of medicine at University of Basel. We notice that the average costs are extremely high in this domain and, as the case of Fribourg demonstrates, are essentially due to the clinical training rather than to the basic education at the university.

d) *Technical sciences*. The two FITs have very similar cost values which tend to be lower than natural sciences. As explained, the Faculty of Architecture at the University of Lugano should be considered as humanities and social sciences, and this is actually confirmed by the enrolment ratios

3.6 Evolution over time

A full analysis of the evolution over time of these indicators would go well beyond the scope of this paper. However, it is interesting to present some information on the evolution of the number of students and the expenditures disaggregated by domain. As shown in Figure 5, not only the number of students in the institutions considered has grown noticeably over the past 25 years, but this growth has been essentially concentrated in the humanities and social sciences, which doubled their total number of students.

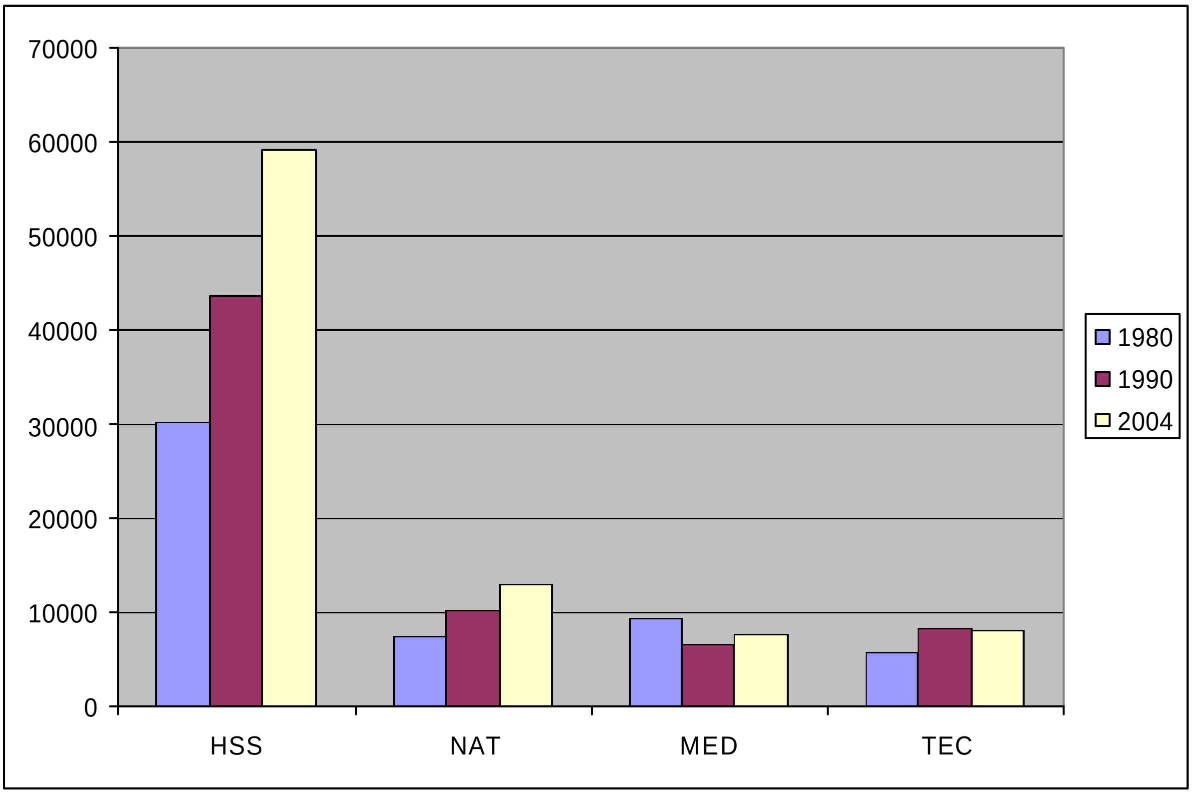

Figure 5. Evolution of number of undergraduate students by domain, 1980-2004

Now, the relevant question is the extent to which the internal distribution of the budget takes into account these differences in the evolution of the number of students. Unfortunately, this is possible only for the short period 1995-2003 since the financial statistics of the universities were completely revised at the beginning of the ’90s, and data for the preceding period are difficult to compare (Lepori 2005).

Considering that no Swiss university possesses a formula-based internal allocation mechanism and that historical considerations play an important role almost everywhere, we suggest that redistribution concerns basically only the increase in the budget, while the previous level is more or less guaranteed. Thus, we can devise two extreme models: in the first one, the increase is distributed to the disciplines proportionally to their share of the budget, regardless of the different evolution in the number of students, while in the second one the increase is distributed according to the increase in the number of students.

Table 5 shows the results for the five universities for which a meaningful comparison is possible.

	All	**SOC**		**NAT**		**MED**	
	Expenditures	Expenditures	Students	Expenditures	Students	Expenditures	Students
BE	107	106	131	102	109	110	92
BS	116	121	113	101	101	152	90
GE	122	125	113	124	92	119	75
LS	136	131	119	99	67	171	87

ZH	132	136	147	140	106	128	91

Table 5. Evolution of expenditures and number of students per discipline , 1995-2003

100 = level of the year 1995. Expenditure data real (adjusted with GDP deflator).

In three cases – Bern, Geneva and Zurich – it is evident that the budget increase was redistributed proportionally in the three domains, regardless of the different numbers of students. Lausanne is quite a special case since a large part of natural sciences was transferred to the EPFL, greatly reducing the number of students; even in this case, this domain kept more or less its previous level of resources. The case of medicine is particularly striking since expenditures increased everywhere in front of decreasing number of students.

4 A Variable Cost Function for the Swiss Universities

A growing body of empirical literature has estimated cost functions for universities. However, no empirical study has been performed on Swiss universities. In the literature we can find studies using a single output approach (e.g. Nelson and Heverth 1992; Koshal and Koshal 1995), studies using a multi-output approach (e.g. Koshal et al. 1999 and 2001) and studies using a multi-output approach, which also consider in the model variables on research performance and/or quality (e.g. Dundar and Lewis 1995; Sav 2004).[6]

All these studies assume that the costs of operating a university are the costs of the building and the equipment, the costs of teaching and the costs of performing research projects. Generally, a university is represented as a firm transforming three main inputs (physical capital, human capital and labor) into three main outputs (undergraduate and graduate teaching and research activities). Moreover, the quality of education and research activities can vary among institutions. Therefore, a cost specification should include in the model some indicators of the quality of these outputs as explanatory variables. Unfortunately, precise information on quality is not always available.

The most relevant studies for our analysis are those by Koshal et. al. (1999) and Sav (2004). Koshal et. al. (1999) used a multiproduct quadratic total cost function to analyze economies of scale and economies of scope using a sample of 158 private and 171 public American universities. The explanatory variables considered in the study are: undergraduate students, graduate students, students per teacher as proxy for quality. Moreover, the average class size and the average total scores on the Scholastic Aptitude Test of entering freshmen are also included in the model specification as proxy for quality. The main conclusion of this study is that American universities appear to exhibit economies of scale and economies of scope; However, product specific economies of scope do not exist for all output levels.

Sav studied the cost structure for a sample of 2189 American private and public universities using data for 1996. This researcher used a multiproduct quadratic total cost function with the following variables: 3 teaching outputs (undergraduate students, graduate students, professional students), and grants received as proxy for the research output. In addition a dummy variable for the presence of a medical school and the price of labor are included in the cost model specification. Empirical results highlight the presence for a part of the institutions included in the analysis of ray economies of scale as well as scope economies.

From the literature on the estimation of cost functions for universities a number of issues can be identified. First, previous studies generally failed to account for unobserved differences between universities. For example, there may be variation of quality and social characteristics. Second, there are aggregation problems associated with the accurate specification of the variables. These occur because the choice of aggregate outputs in terms of number of undergraduate and graduate students masks large differences between components of the aggregated discipline (i.e., medicine and the social, natural, and engineering sciences). Third, the measurement of research activities is difficult because of the lack of indicators such as number of publications, number of research projects realized for the private sector and number of grants received from scientific research institutions. Fourth, the majority of the studies assume that universities do attempt to minimize total costs. This assumption may be questioned on the grounds that universities are nonprofit institutions and that capital (buildings) is more a quasi-fixed factor.

The two major improvements of this study in comparison to some of the previous studies are: a) the use of a restricted variable cost model, which recognizes disequilibrium in that the quantity of physical capital cannot be adjusted to achieve minimum total cost in the short run for a given set of input prices and the quantity of outputs; b) the use in the econometric estimation of the cost function of a random effects model that takes into account, at least partially, the heterogeneity of the universities; c) the definition of the outputs at the level of two aggregated disciplines.

For the specification of the cost model for this research we have considered a university with two inputs, labour (L) and capital (C), which produces two teaching outputs.[7] Moreover, in the cost model

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[6] In the literature you can find two pioneering studies which estimated a multiproduct cost function for higher education institutions. See Cohn et al. (1989) and de Groot et al. (1991).

[7] Unfortunately data on material price are not available. However, this price should be more or less the same for all universities. Therefore, the effect of this input price on cost is considered in the constant.

specification we include a variable, which should capture, at least partially, the quality dimension of the university's outputs. Unfortunately, we were not able to include in the model specification a variable representing the research activities, because of a multicollinearity problem and lack of information on publications. Of course, we are aware that the omission from the model of a variable on the research activities could bias the empirical results. Future research on the cost structure of the Swiss universities should try to consider more precise information on the research activities, such as the number of publications in peer reviewed journals.[8]

If the transformation function satisfies certain regulatory conditions (Lau 1976), and if universities minimize variable costs, the variable multiproduct cost function for the Swiss universities may be written as

$$VC = V(Y_{SS}, Y_{NSM}, P_L, C, Q, T) \qquad (1)$$

where VC represents total variable cost, Y_{SS} is the number of students enrolled in social science departments and Y_{NSM} is the number of students enrolled in an engineering department, a natural science department or in a faculty of medicine.[9] We did not include in the model a variable representing the number of PhD students, since in Switzerland PhD students are generally employed by the universities as teaching or research assistants, and they do not have to follow a structured PhD program with doctoral courses. Therefore, the number of PhD students can be also considered a proxy for an input. PL is the price of labor, and C is the capital stock. Q is the teaching staff ratio, which is the ratio of the number of teaching staff in a university to the number of students. Since the university activity is a labor-intensive service and the quality of teaching depends also on the time spent by professors and assistants for each student, this variable should represent a dimension of the quality of output and the production process. T is a time variable which captures the shift in the technology representing change in technical efficiency.

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[8] In the first part of the empirical analysis we included in the cost model specification the sum in Swiss francs of the grants obtained by each university as proxy for the level of research activities. Unfortunately, we found a multicollinearity problem given by the high correlation between the number of students and the amount of research founds. Moreover, data on publications are not available for all disciplines. For this reason we decided to use only two outputs related to teaching activities.

[9] The data considered in this study refer to a period in which the Swiss university system did not distinguish between study for the bachelor's degree and for the master's degree. For this reason, we employed the total number of graduate and undergraduate students as output indicators.

Following Koshal and Koshal (1999) and Koshal and Koshal (2001) we assume that variable cost (VC) of education output can be represented by a flexible cost quadratic function. Mayo, (1984) and Baumol Panzer and Willig (1988) recommend the use of a quadratic cost for estimating scale and scope economies for most types possible of multiproduct organizations.[10] This flexible functional form is a local, second-order approximation to an arbitrary cost function. It places no a priori restrictions on the elasticities of substitution and allows the economies of scale and scope to vary with the output level.[11] Due to the relatively small sample used in this study, second order coefficients are estimated only for the output variables. Therefore, the quadratic approximation to (1) is

$$\begin{aligned} VC &= a_0 + a_{SS} Y_{SS} + a_{NSM} Y_{NSM} + \frac{1}{2} a_{SS} (Y_{SS})^2 + \frac{1}{2} a_{NSM} (Y_{NSM})^2 \\ &+ a_{SSNSM} (Y_{SS})(Y_{NSM}) + a_C C + a_{PL} P_L + a_Q Q + a_T T + e \end{aligned} \tag{2}$$

The properties of cost function (2) are that it is concave and linearly homogeneous in input prices, non-decreasing in input prices and output, and non-increasing with respect to capital stock.[12]

4.1 The data

This study is based on a combined time series and cross-sectional data set for 12 universities operating over the period 1994-2002 in Switzerland (see section 2 and the appendix for detailed description). Variable cost is taken to be the sum of labor, energy and material costs. Outputs are measured in total number of students enrolled in humanities and social science departments and in faculties of natural science or medicine. Average yearly wage rates are estimated as the weighted mean of the average wage rates of the different professional categories working in a university: professors, research and teaching assistants, administrative and technical staffs.[13]

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[10] One of the shortcoming of this functional form is the impossibility to impose the linear homogeneity condition on the parameters. However, for the analysis of the economies of scope, this function possess clear advantages in comparison to other functional forms. For a discussion on the advantages and disadvantages of this functional form see Chambers (1988). In any case, because we are considering only one factor price in this study, the linear homogeneity problem is not relevant.

[11] A quadratic function requires the approximation of the underlying cost function to be made at a local point, which in our case is taken at the median point of all variables. Thus, all independent variables are normalized at their median point.

[12] See Cornes (1992), p. 106.

[13] In the first part of the empirical analysis we estimated a model with three different input prices (professors, teaching assistant and administrative staffs). However, due to the high correlation between these variables and the relatively small sample, we decided to use a weighted average of these input prices.

The capital stock is approximated by the number of squared meters owned and operated by a university. Unfortunately no data are available which would allow us to calculate the capital stock using the capital inventory method. The input prices and variable costs were deflated to 2000 constant Swiss francs using the Consumer Price Index. Table 1 lists means and standard deviations of the main variables.

	Mean	STDEV	Median
Number of students social science (Y_{SS})	**4551**	**3886**	**4112**
Number of students natural science (Y_{NSM})	**2510**	**2467**	**2085**
Number of square meters (K)	**121941**	**91142**	**114030**
Average labor price (P_L) in SFr per employee per year	**109675**	**12513**	**109760**
Teaching staff ratio *(R)*	**32.3**	**10.7**	**28.54**

Table 6. Descriptive statistics

4.2 Estimation Results

With regard to the choice of the econometric technique, it should be noted that in the econometric literature we can find various types of models focusing on cross-sectional variation, i.e., heterogeneity across units. The three most widely used approaches are: the OLS model, the fixed-effects (LSDV) model, and the random-effects model (GLS).[14] In this study we assume that the individual constants are random variables. In this case, differences between units are not viewed as parametric shifts of the regression function as in the LSDV model, but as randomly distributed shocks. We excluded the LSDV model because it is not possible to estimate the parameters of time-invariant observations, e.g., the coefficient of the capital stock included in (2). Moreover, the within variation of some variable is relatively small.[15] Thus, equation (2) is estimated using the GLS model.[16]

The estimated coefficients of the quadratic cost model (2) are presented in Table 2. The results are satisfying in so far as all first order coefficients and part of the second order coefficients are significant and carry the expected signs.

[14] For a detailed presentation of the econometric methods that have been used to analyse panel data, see Balestra and Nerlove (1966), Greene (2003) and Hsiao (2002).

[15] For a discussion of this issue see Farsi et al. (2005a).

[16] In order to decide between the OLS model and the GLS model we employed the Lagrange Multiplier test. The results of this test show that the GLS should be preferred to OLS.

The cost elasticity with respect to the output characteristics variables, Y_{SS} and Y_{NSM}, are positive and imply that an increase in the number of students inscribed in the different disciplines will increase variable cost. As expected the coefficient of the labor price is positive, implying that the cost function grows monotonically in this input price.

The coefficient of capital stock is positive, pointing to increases in variable costs with increases in capacity at the sample median. This result indicates that the regularity condition of non-increasing variable cost with respect to the capital stock is not satisfied at the median of the data. [17]

As expected, an increase in the teaching staff ratio has a negative impact on the variable costs. Finally, the coefficient of the linear trend suggests that the total costs have increased over time. This phenomenon might be explained by a general growth of labor price and by a general increase in research activities, which, as explained before, have not been considered in the model.

Parameters	
Constant	220365000*** (46818700)
a_{QT1}	19928.34*** (5610.42)
a_{QT2}	29324.52** (11698.23)

[17] In the literature we can find two possible interpretations of this theoretically implausible sign of the coefficient of capital stock. The first interpretation, proposed by Cowing and Holtmann (1983) argues that the positive sign of the coefficient of capital stock is an indicator of an excessive amount of capital stock employed by the firms. In this case, an increase of the capital stock would lead to an increase of both variable and fixed costs. The second interpretation, proposed by Guyomard and Vermersch (1989) and sustained by Filippini (1996), supports the idea that the incorrect sign of the coefficient of the capital stock is probably derived from multicollinearity between the output and the variable used to approximate the capital stock. We believe that in our case, due to the fact that we are measuring the capital stock using a physical variable, the second interpretation is more appropriate. In fact, the correlation coefficients between the proxy for the capital stock and the outputs is very high.

a_{QT11}	1.894** (0.674)
a_{QT22}	0.288 (3.906)
a_{QT12}	-0.892 (2.022)
a_K	1708.253*** (310)
a_{PL}	775.477** (291.058)
a_T	4228860*** (929463.706)
a_{QU}	-1551810** (602917)

*, **, *** significantly different from zero at the 90, 95 and 99 % confidence level.

Table 7. Total cost parameter estimates (standard errors in parenthesis)

4.3 Short-run marginal cost, economies of utilization and short-run economies of scope

In Table 3, we present the marginal cost of each product for different levels of output along with the proportional output ray. The short-run marginal cost values are computed at the median values of the explanatory variables. This means that the values reported in Table 8 reflect the situation of a hypothetical higher education institution. Moreover, the estimated cost greatly depends on the assumed mix of disciplines. An examination of the values reported in Table 3 suggests that, for all levels of output, the marginal cost of social science students is lower that for natural science or medical students.

% of median output	MC_{SS} ***(Social science)***	MC_{NCM} **(natural science and medicine)**
50	18913	31004
75	19420	30164
100	19928	29324
125	20436	28484
150	20943	27644

Table 8. Marginal Cost estimates (Swiss Francs)

We note that these values are quite different compared to the amount of money paid to the university cantons by the cantons of origin of the students for the costs of their education (9,500 sfr. per year for the humanities and social sciences, 23,000 sfr. for natural and technical sciences and medicine, 46,000 sfr for medicine from the 3rd year). Since these are based on estimations of the educational costs, this could be an indication of changes in research intensity with number of students.

The inclusion of an indicator of the capital stock in the variable cost function allows the calculation of economies of capacity utilization. Following Caves and Christensen (1988), economies of capacity utilization are defined as the proportional increase in variable cost resulting from a proportional increase in outputs, holding capital and the other factors fixed. Ray (overall) economies of utilization are defined as follows:

$$ECU_{VC} = \frac{VC(Y_{SS}, Y_{NSM})}{MC_{SS}Y_{SS} + MC_{NSM}Y_{NSM}} \qquad (3)$$

where VC (Yss, Y_{NSM}) is the variable cost of producing Yss and Y_{NSM}, $MCss$ ($MCss = \partial VC / \partial Yss$) is the marginal cost of producing Yss, and MC_{NSM} is the marginal cost of producing Y_{NSM}.

We will talk of economies of capacity utilization if ECU_{VC} is greater than 1, and accordingly, identify diseconomies of capacity utilization if ECU_{VC} is below 1.

Given that teaching social science students and teaching natural science students are performed within the same university, it is possible that their production entails economies of scope. In the case of two outputs, following Panzar and Willig (1979) and Toft and Bjordal (1997), short run economies of scope exist if

$$TC(y_L, y_H) \prec TC(y_L, 0) + TC(0, y_H) \qquad (4)$$

In any production process, economies of scope are present when there are cost efficiencies to be gained by joint production of multiple products, rather than by being produced separately. The degree of short-run economies of scope in the production of two products is defined as

$$ES = \frac{VC(Y_{SS}, 0) + VC(0, Y_{NSM}) - VC(Y_{SS}, Y_{NSM})}{VC(Y_{SS}, Y_{NSM})} \qquad (5)$$

Global economies (diseconomies) of scope are said to exist if ES is greater (less) than zero.

In Table 9, we present the value of ray economies of capacity utilization and economies of scope. The values presented in this table suggest that ray economies of capacity utilization apply to all output levels ($ECU_{VC} > 1$). The fact that increased capacity utilization would result in reductions in ray average variable cost implies that the Swiss higher education institutions are characterized by excess capacity. Moreover, an examination of the values reported in the third column of Table 9 reveals that global economies of scope exist for the output range considered in this analysis (ES > 0). Therefore an unbundling of a multi-disciplines university into single-discipline university leads to higher costs as the synergies in the joint production are no longer exploited.

% of median output	ECU_{VC}	ES
50	5.49	0.84
75	3.97	0.77
100	3.22	0.72
125	2.77	0.68
150	2.48	0.64

Table 9. Ray economies of capacity utilization and scope

5 Discussion

The main goal of this study was to provide an initial explorative analysis on the cost structure of the Swiss higher education institutions using a number of simple indicators as well the results obtained from the econometric estimation of a cost function. For this purpose, a panel data of all Swiss higher education institutions over the period between 1994 and 2002 has been analyzed. To our knowledge, this is the first attempt to perform an analysis of the cost structure of these Swiss institutions. Moreover, the analysis has been performed at the aggregate level as well at the disaggregated, i.e. at the level of disciplines; this is quite rare in the European context given the limitations of the available data (see Jongbloed and Salerno 2004 for the Dutch case).

In the empirical analysis based on simple indicators we could show that differences between main disciplinary groups are very large indeed, not only concerning costs levels, but also for other important indicators like PhD degrees, enrolment ratios and staff structure. For these indicators, differences between disciplinary groups are actually larger than differences between universities. We notice also that the significance of the average costs per student calculated for the whole university is limited, since for universities like Bern, Geneva, Lausanne or Zurich, no group of disciplines actually has an average cost per student close to the average for the whole university. This means that comparisons of the cost between universities can be easily distorted if we do not consider the share of different domains covered by the higher education institutions. For instance, in universities with a full curriculum in medicine, this domain accounts for less than 10% of the undergraduate students, but for more than 50% of the total expenditures. Thus, more refined ways to take into account subject mix have to be developed even in countries where data cannot be disaggregated.

Moreover, even with a small number of observations, results disaggregated by discipline reveal some interesting patterns with size, meaning perhaps that the lack of clear results for universities as a whole might depend on their heterogeneity. In the humanities and social sciences, as the number of student increases, enrolment ratios increase strongly, but at the same time there is more academic support staff per professor. Thus, when the number of students increases, universities react by increasing class size – which is relatively easy in domains where lectures are the main teaching model –, but at the same time they enroll more staff for duties like student support, tutoring, exams etc. However, in the Swiss model, teaching assistants are normally PhD students at the same time, and thus the volume of research automatically increases with the increasing number of students as indicated by the number of PhD degrees per undergraduate students.

This result critically depends on the strength of the joint research and teaching model in Swiss universities, since there are other possible models to cope with increasing numbers of students, such as going to a stronger specialization between institutions or curricula in research intensity. We notice that the number of students is very low, with an average for natural sciences, medicine and technical sciences as low as 2500 students; in natural sciences all universities except the ETHZ have less that 2000 students, while the largest medicine department at the University of Zurich has 2000 students, with costs higher than those for the 15,000 students in the whole human and sciences.

Our hypothesis is, however, that in these domains the level of costs is essentially driven by research activities: the strength of the Humboldtian model means that for most subjects taught in curricula there has to be research activity, meaning a research team of minimal size, regardless of the number of students. Moreover, these domains have a much higher share of external funds than the humanities and social sciences. Since in the Swiss context most third party funds provide only salaries for PhD students, this implies an increase in the funding of research from the general budget, a trend confirmed by recent data from the analytical accounts of the universities (Conférence Universitaire Suisse 2006). Moreover, we found that some indications are to some extent the effect of a rigid allocation of funds according to domains in the face of numbers of students which increased more noticably in the humanities and social sciences than in the other domains.

In the second part of the paper we provide an empirical analysis of the cost structure of the Swiss universities using an econometric approach. The analysis considers the estimation of a variable cost function. A quadratic cost function was estimated using panel data for 12 Swiss universities, 1994-2002. The results show that the university sector is characterized by the existence of economies of capacity utilization and by economies of scope. This implies that the Swiss higher education institutions are characterized by excess capacity and that an unbundling of a multi-discipline university into single-discipline university leads to higher costs as the synergies in the joint production are no longer exploited.

In general the quality of the available data is acceptable for an initial explorative econometric analysis of the cost structure of the Swiss universities. However, from a methodological and data point of view this empirical analysis suffers from two problems. First, because of the limited number of observations, some of the advanced panel data models could not be used. Second, the model specification did not consider as explanatory variable an indicator of the research activities. Given these problems, the empirical results reported in this paper should be considered with caution.

Generally we contend that the data can be improved. In particular, potential data improvements can be considered in the accounting of capital investments and amortization and in the reporting of some indicators on the research activities of the universities. Such improvements can be helpful from a methodological standpoint in that they allow to compute more precise indicators concerning research and research funding and allow the application of more accurate econometric models and functional forms.

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8 Annex: variables, source data and methodological comments

Variable	Definition and coverage
Undergraduate students	Students in the basic university curriculum (4 years diploma or six years in medicine). Since 2000 some universities introduced the Bologna model: this category comprises also all students enrolled in bachelor and (Bologna) master degrees. Data refer to the beginning of the academic year (October). Headcount. Source: SFSO.
PhD students	Students officially enrolled as PhD students (not necessarily in structured programs or paid by the university). Data refer to the beginning of the academic year (October). Headcount. Source: SFSO.
Undergraduate degrees	Undergraduate diplomas (4 years normally, except for medicine), as well as Bologna master diplomas (five years); excludes three-year Bologna bachelor diplomas. Source: SFSO.
PhD degrees	Number of PhD degrees awarded during the calendar year. Source: SFSO.
Staff	Number of staff employed by the university with any form of contract (stable or temporary). Since in Switzerland there is no uniform classification of university personnel, SIUS translates the categories used in each university in XVIII personnel categories, which are then grouped in four main categories: 1. Professors: *full, associate* and assistant professors. 2. Upper academic staff, mainly with teaching duties; 3. Lower academic staff, including research and teaching assistants (most of the PhD students are in this group). 4. Technical and administrative staff. For this analysis, we merge groups 2 and 3 comprising all academic staff except professors (other academic staff). All data are in Full Time Equivalent (data on counts are also available if needed). Source: SFSO.
Expenditures	University expenditures in SIUS cover only following categories: • All staff costs, including social charges. • Operating costs (travel, consumables, maintenance). Expenditures include also some costs which would be considered part of capital costs, like amortization and rent; however, data show that these costs are low (max. 5% of total expenditures). Expenditures do not include capital costs, nor investments, which are normally accounted for separately (or are included directly in the state expenditures).

	The central domain comprises the central administration of the university, the central services and costs and other expenditures which cannot be divided (for example buildings used jointly by different departments). Since the share of expenditures in the central domain varies considerably according to the university (in 2002 from 10% for UNIBAS to 31% for UNISI), reflecting probably different accounting methods, when considering data for single activity domains, we distribute these central costs proportionally for each expenditures category (thus separately for each personnel category and for operating expenditures). Source: SFSO.
Capital stock	Due to different legal status and ownership of buildings, there are no complete data on the physical resources available to universities. However, the Swiss University Conference produced an estimation of the floor space available for each university (divided by main disciplinary group. We use the data for 1999 (the latest data available) since we do not expect that floor space is changing rapidly (except for University of Lugano which was only founded in 1996). More recent data will available shortly. Source: SFSO.
ISI publications	ISI publications data for Swiss universities have been published by the Centre for Studies of Science and Technology (www.cest.ch). Total number of ISI publications is available for a five-year mean from 1981-1985 to 1998-2002; the number of publications by subdomains is available only as a mean for the years 1997-2001. There are no data on the three smallest universities. Source: CEST 2003.

Table 9. Variables used and methodological comments

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