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

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8.1 INTRODUCTION

In today's economic and financial environment, the issues of costs and the cost structure of higher education institutions (HEIs) are increasingly relevant even in countries such as Switzerland where universities have traditionally been comparatively well funded with respect to the number of students.

The issue leads to a set of different questions: the first concerns allocative and cost efficiency, that is, 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); the second concerns scale efficiency, that is, the extent to which institutions operate at an optimal size; the third 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, Daraio and Simar, Chapter 5).

A further issue concerns the reasons for the large differences in cost levels per student between 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 in fact there are very few general results 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 mission of HEIs). Also, the evidence concerning returns to scale in higher education and trade-offs between education, research and third mission is at the very least ambiguous (Bonaccorsi and Daraio, Chapter 2). Analysis at the discipline level is 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 puts severe limits on the analysis.

In this chapter, we propose an analysis of the cost structure of Swiss HEIs. 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 regard to both outputs and operation conditions. However, simple indicators can be useful in understanding the variation patterns of different factors among HEIs and between different domains.[1]

In the second stage, the cost structure of 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 to take into account not only the observed differences among hospitals 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 be 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 the Swiss higher education policy. Namely, the system of governance and funding of higher education is extremely complex and fragmented (see Lepori, Chapter 6), 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 Écoles 2008', 2004). Since standard costs will be based on the actual situation, it is crucial to assess to what extent 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 practical work – to differences in the level of research and teaching activities, or whether they are the result of internal allocation that favoured some domains and, for example, allowed some domains to fund research to a greater extent through the general budget of the university. Failure to assess this could result in an ineffective and inefficient funding system.

The chapter is organized as follows. In Section 2, we briefly present our sample, as well as the available data. In Section 3, we produce a set of indicators to characterize Swiss HEIs and we perform a cross-analysis between institutions and main discipline groups. In Sections 4 and 5, 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, Section 6 proposes some interpretations of the results, as well as methodological implications for the field of study.

8.2 THE SAMPLE AND THE AVAILABLE DATA

Our sample is composed of the 10 Swiss cantonal universities and the two federal institutes of technology (FITs; see Table 8.1). We recall that the two FITs are directly ruled and completely financed by the Confederation, 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, Chapter 6, for more details). We exclude the seven universities of applied sciences, since they differ considerably in the structure of their curricula, as well as in activities (lower R&D activity share).

Note that there are strong differences concerning the subject mix between 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 are relevant since we shall show later that average cost per student differs strongly 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. 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 Appendix 8A full details):

- education: number of undergraduate students and number of PhD students; number of degrees and PhD degrees;

Table 8.1 Basic data on higher education institutions, 2002

Name	Abbreviation	Foundation	Undergraduate students	Human and social sciences	Natural sciences	Technical sciences	Medicine
University of Basel	UNIBS	1460	6307	X	X	–	Y
University of Bern	UNIBE	1528	10,219	X	X	–	X
Federal Institute of Technology Zurich	ETHZ	1854	9275	–	X	X	–
Federal Institute of Technology Lausanne	EPFL	1968	4465	–	X	X	–
University of Fribourg	UNIFR	1889	8634	X	X	–	Y
University of Geneva	UNIGE	1559	10,132	X	X	–	X
University of Lausanne	UNIL	1537	7851	X	X	–	X
University of Lugano	UNISI	1996	1481	X	–	X	–
University of Luzern	UNILU	1574	536	X	–	–	–
University of Neuchâtel	UNINE	1838	2598	X	X	–	–
University of Sankt Gallen	UNISG	1898	4104	X	–	–	–
University of Zurich	UNIZH	1833	19,104	X	X	–	X

Note: Y: only part of the curriculum.

- staff in full-time equivalent divided into three categories: professors; other academic staff; technical and administrative staff;
- expenditures divided between personnel (divided by personnel category) and functioning 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 from the state budget. Note that for the practice years in clinical medicine the separation between higher education and healthcare costs is quite problematic and this could strongly affect 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; and
- ISI (Institute for Scientific Information) publications.

All data are disaggregated by university and activity domain; SIUS provides for a very detailed breakdown according to a list of 81 activity domains which are then grouped into seven main discipline groups (human and social sciences; economics; law; exact and natural sciences; medicine and pharmacy; technical sciences; interdisciplinary and other) plus a central domain for central personnel and expenditures which cannot be divided. Note that these activity domains do not correspond to organizational units, but are constructed by grouping departments and research institutes according to their main activity domain.

For this analysis, we regroup the domains into four, including economics and law in human and social sciences.[3] This division is similar to that used by Jongbloed and Salerno (2004) using a three-discipline cluster (human and social sciences; medicine; natural and technical sciences); the separation of technical sciences is justified since these are present only in the two FITs.

Time coverage for these data is 1994–2003 except for publication data where five-year means from 1981–86 to 1997–2001 are available and were approximated to yearly values. All monetary values have been converted in 2000 Swiss francs (SFr.), adjusted for inflation using GDP deflator series.

8.3 COSTS AND COST STRUCTURES

In this section, we produce and analyse 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 universities and, finally, we compare in more detail some activity domains between all universities. In this part of the analysis we do not consider explicitly any measure of productivity or efficiency, because one needs to define relevant measures of outputs and inputs, but we focus rather on differences between universities and domains.[4]

8.3.1 The Selection of the Indicators

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

1. *Cost indicator* We consider here the total running costs of the university divided by the number of students (average cost per undergraduate student). Note that in this analysis, we consider 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 the personnel using the methodology of the Frascati manual (OECD, 2002). However, the quality of these data has to be questioned: first, 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 and education (Jongbloed and Salerno, 2004). For this reason, we prefer to control for research intensity using other indicators.[5]
2. *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 the number of degrees has some methodological problems (for example, time lag; Salerno, 2004). For the measure of the quality, the simplest indicator is the number of students per professor.
3. *Structure of the personnel* We adopt the number of academic staff per professor as the main indicator of the structure of personnel.
4. *Research intensity* In the literature, some indicators are discussed to measure research intensity (see Slipersæter, 2005 for a review). The simplest, being the main criterion used in the Carnegie classification of US universities, is the number of PhD degrees per 100 undergraduate students. Scientific publications from the ISI are also regularly used, but with the main drawback of not covering adequately human and social sciences (Hicks, 2004). An alternative indicator which has been used by many is the share of third-party funds and, especially, of competitive research grants. Its main drawback in this context is,

however, that it is strongly dependent on the subject mix since competitive funds are distributed quite unevenly according to the disciplines.
5. *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 students and for staff.

8.3.2 University-level Analysis

Table 8.2 presents the basic indicators for the 12 Swiss universities and FITs considering the HEIs as a whole. Some results are very evident.

First, 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.

Second, 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. Note that these values are quite high in an international comparison (Slipersæter et al., 2005). ISI publications per student also show some variations, but we have to consider that the lowest values concern universities with a very high share of human and social sciences. In the Swiss case, human and social sciences account for only 4 per cent of the total ISI publications (CEST, 2003).

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

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

8.3.3 The Importance of the Subject Mix

We now examine to what extent differences in average costs are linked to different subject mixes and, in particular, to specialization in natural and technical sciences of the two FITs, as well as to the presence of a faculty of

Table 8.2 *Basic data and indicators for Swiss universities, 2002*

HEI	Undergrad. students	Costs per undergrad. student	Sq. m. per undergrad. student	Sq. m. per staff	PhD degrees per 100 undergrad. students	Undergrad. students per professor	PhD students per professor	Academic staff per professor	Avg. labour price	Publications per 100 undergrad. students
Bern	10,219	51,537	10.2	32.8	5.1	38	5	6	100,373	16
Basel	6307	50,949	24.9	73.1	6.4	24	6	5	102,708	22
EPFL	4465	104,283	35.9	54.3	5.1	26	5	11	115,410	22
ETHZ	9275	99,229	35.9	52.8	6.7	27	7	12	102,189	25
Fribourg	8634	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	7851	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	2598	45,644	15.1	49.5	3.7	23	4	4	112,973	9
Sankt Gallen	4104	31,301	6.8	42.4	3.1	59	12	5	139,420	NA
USI	1481	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	7059	51,182	15	45	3	34	6	6	114,448	7059
Std dev.	5064	25,942	11	13	2	12	3	3	15,371	5064
Median	7079	44,826	12	43	3	29	5	5	113,959	7079

Note: All data in 2000 Swiss francs; square meters: 1999 data.

medicine in some cantonal universities. As a first approach, Table 8.3 shows the average cost per student by university and discipline group.

In interpreting this table, we need to take into account some specific features which affect the 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; also, the ETHZ offers pharmacy only; for Basel, medicine costs are underestimated since not all contributions to the cantonal hospitals are included in university expenditures.
- In technical sciences, USI offers only a curriculum in architecture with a strong orientation towards human and social sciences and thus cannot be compared with the ETHZ; also, the provision in Neuchâtel is very small – only 38 students.

Note that differences in average costs between groups of disciplines are very large, but that the differences in average costs between universities in the same discipline group are lower; this is especially apparent in the two domains where we have many observations, namely human and social sciences and natural sciences. This analysis significantly modifies the

Table 8.3 Expenditures per undergraduate student by university and discipline group, 2002

	Human and social sciences	Natural sciences	Medicine	Technical sciences	All
BE	14,142	82,754	199,491		51,537
BS	19,852	164,487	76,421		50,949
EPFL		139,302		87,657	104,283
ETHZ		101,340	59,082	91,191	99,229
FR	15,165	77,291	79,260		22,082
GE	21,886	212,023	246,017	144,808	59,313
LS	17,299	109,162	136,243		43,745
LU	34,031				34,031
NE	18,577	141,457		421,574	45,644
SG	31,301				31,301
USI	15,370			53,893	28,064
ZH	13,427	109,333	221,058		44,009
Mean	20,105	126,350	145,367	159,825	51,182
Std dev.	7147	42,878	76,856	149,898	25,942

Note: See Table 8.1 for abbreviations.

position of the two FITs: in natural sciences, where we can compare with cantonal universities, ETHZ and EPFL have costs which are similar to cantonal universities in the corresponding domains. It is only the fact of averaging with human and social sciences that gives lower aggregate values for cantonal universities.

8.3.4 Personnel and Cost Structure by Discipline

Figures 8.1 and 8.2 also show very significant differences concerning the structure of staff and of costs by main discipline groups. The most striking difference concerns the share of professors both in staff and in costs: they account for 15 per cent of full-time equivalent (FTE) and for 22 per cent of total costs in human and social sciences, but for slightly more than 5 per cent of FTE and about 10 per cent of the total costs in the other domains (5 per cent of the costs in medicine). As expected, functioning expenditures are much higher in 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.

8.3.5 A Detailed Analysis the Different Discipline Groups

Table 8.4 presents the basic cost indicators for each university for the four main discipline groups used in this analysis. They lead to the following main remarks:

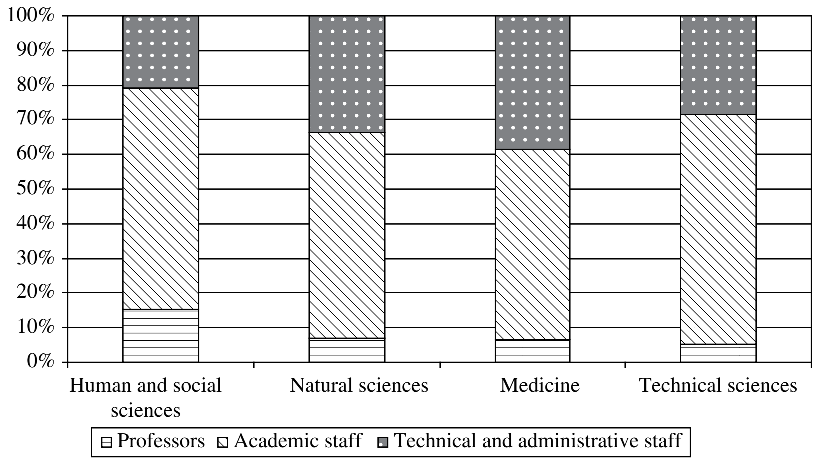

Figure 8.1 Structure of staff by main discipline groups, FTE, 2002

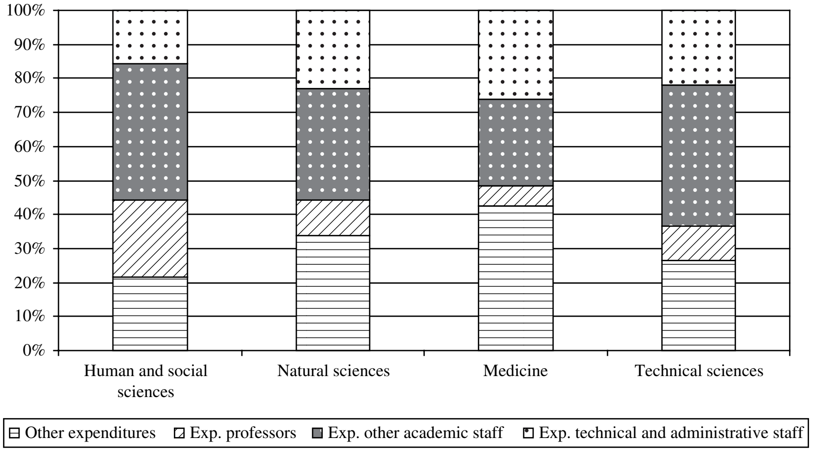

Figure 8.2 Structure of expenditures by main discipline groups, 2002

1. *Human and Social Sciences* Note that there are two outliers concerning average costs which can readily be explained by their different curricula composition. Namely, Sankt Gallen is essentially a business school and most of the students are concentrated in economics; Luzern, besides being the smaller in the sample, covers only theology, human sciences and law and thus lacks the 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 student is only about 20 per cent and most other indicators also show limited variation.

   Figure 8.3 plots the main indicators according to the number of undergraduate students. Note 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 professor 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 per professor increases strongly; since a significant share of academic staff is composed of PhD students, the number of PhD degrees per undergraduate student also shows an increasing trend. We shall come back to interpreting the meaning of these results in the last section, in the light of the econometric analysis.
2. *Natural sciences* It is immediately evident (Figure 8.4) that the number of students is much lower and variation between the largest

Table 8.4 Indicators for the main discipline groups, 2002

	Undergrad. students	Costs per undergrad. student	Sq. m. per undergrad. student	Sq. m. per staff	PhD degrees per 100 undergrad. stud.	Undergrad. students per prof.	PhD students per prof.	Academic staff per prof.	Avg. labour price
Human and social sciences									
Bern	7176	14,142	5.0	42.3	0.8	67	5	6	105,192
Basel	4273	19,852	10.6	90.3	1.9	47	7	4	133,625
Fribourg	7681	15,165	4.1	34.5	0.7	51	5	4	96,975
Geneva	8283	21,886	5.2	36.9	1.0	46	4	4	127,023
Lausanne	5950	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	2113	18,577	5.6	44.9	1.1	32	4	2	128,257
Sankt Gallen	4104	31,301	6.8	42.4	3.1	59	12	5	139,420
USI	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	5651	20,105	5.6	45.0	1.1	48	6	4	121,469
Std dev.	4388	7147	2.1	18.1	0.8	18	3	1	16,120
Natural sciences									
Bern	1559	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	1404	139,302	38.4	46.3	7.3	21	5	11	113,004
ETHZ	4195	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	1645	109,333	45.9	72.9	9.4	25	9	10	98,872
Mean	1378	126,350	46	58	13	18	7	8	101,731

Table 8.4 (continued)

	Undergrad. students	Costs per undergrad. student	Sq. m. per undergrad. student	Sq. m. per staff	PhD degrees per 100 undergrad. stud.	Undergrad. students per prof.	PhD students per prof.	Academic staff per prof.	Avg. labour price
Std dev.	1137	42,878	14	17	3	6	2	2	8033
Medicine									
Bern	1485	199,491	14.3	15.2	18.3	15	5	6	95,115
Basel	1113	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	1219	136,243	18.9	33.3	5.5	10	4	3	128,698
Zurich	2054	221,058	39.1	32.6	16.4	19	8	12	115,163
Mean	1055	145,367	30	45	10	19	6	6	107,567
Std dev.	631	76,856	15	30	7	12	4	4	11,804
Technical sciences									
EPFL	3061	87,657	34.6	59.8	4.1	29	5	11	116,991
ETHZ	4755	91,191	40.3	62.2	3.8	32	7	14	101,973
USI	488	53,893	8.2	32.0	0.0	50	0	7	116,140
Mean	1680	159,825	55	57	6	26	5	9	113,809
Std dev.	2128	149,898	43	19	8	17	4	4	8303
Median	488	91,191	40	60	4	29	5	11	116,140

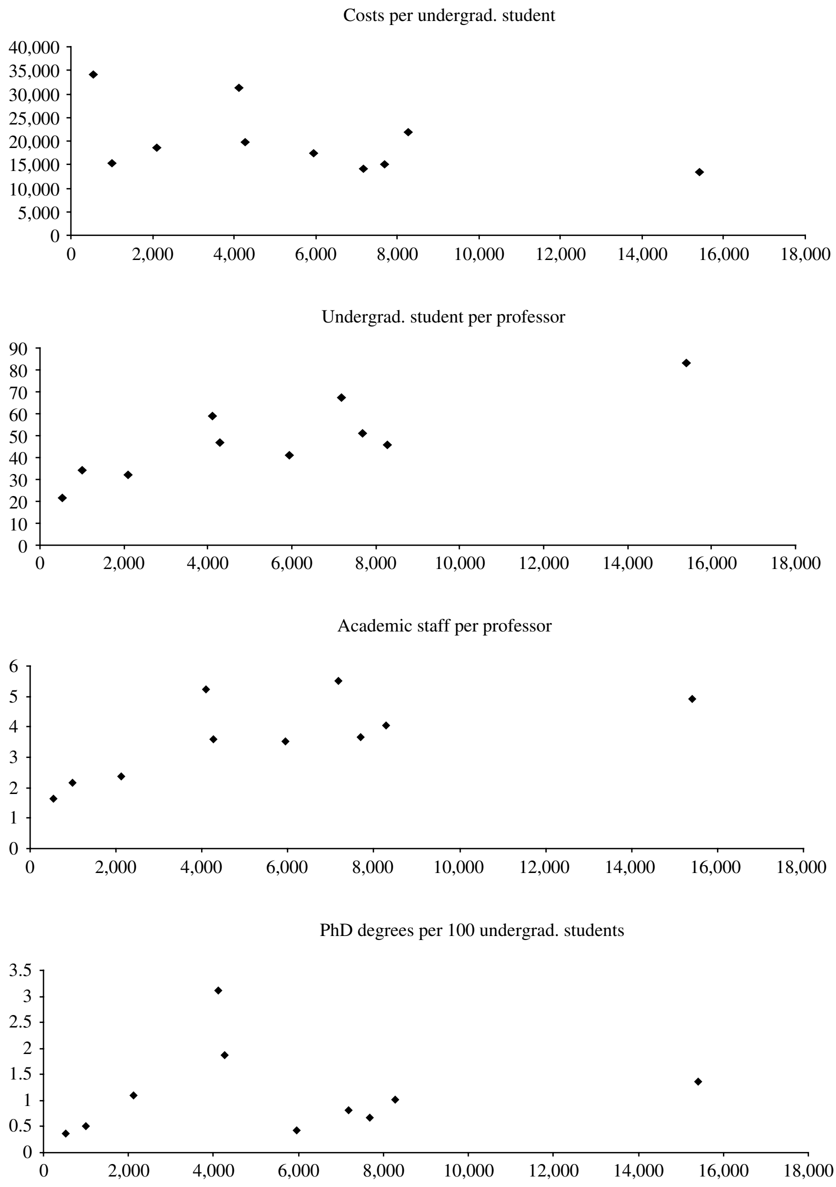

Figure 8.3 Main indicators by number of students, human and social sciences

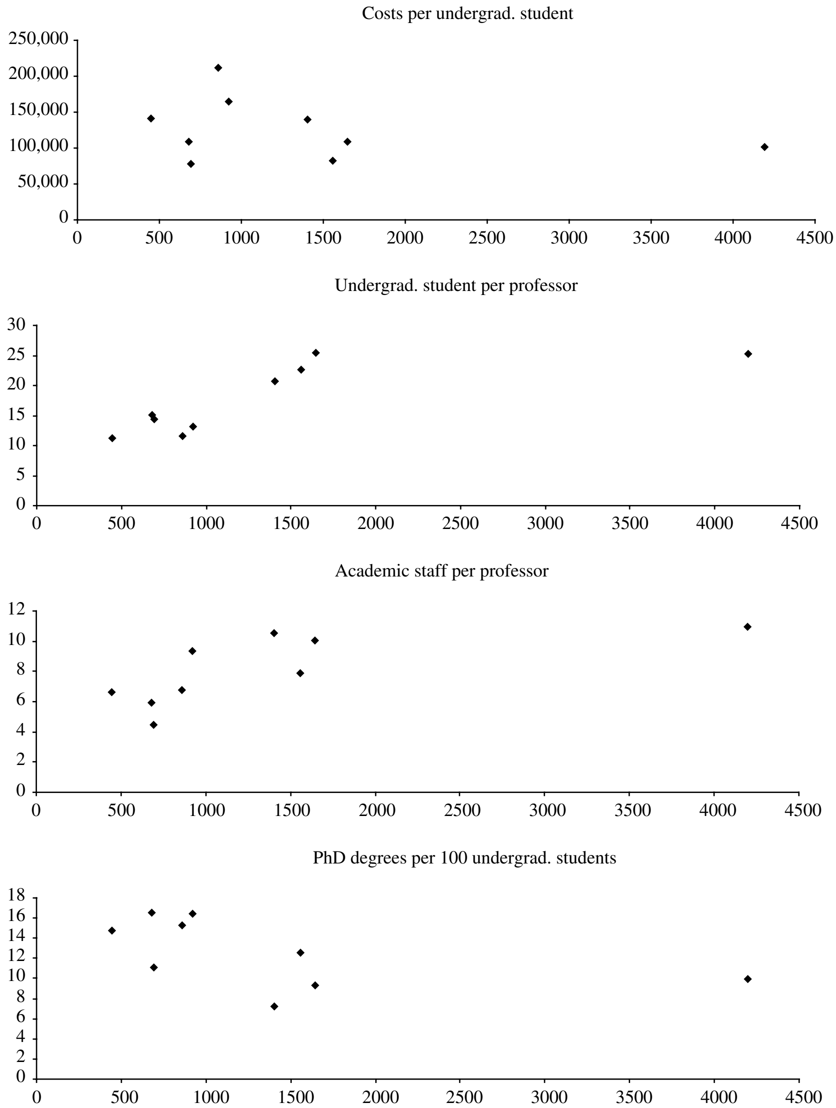

Figure 8.4 Main indicators by number of students, natural sciences

and the smallest university is smaller than in human and social sciences if we exclude the ETHZ, 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 according to size; the number of students per professor is much lower than in human and social sciences for the whole size range. However, costs per undergraduate student and PhD degrees do not show clear trends with size.

3. *Medicine* A reasonable comparison is only possible between Bern, Geneva, Lausanne and Zurich. Fribourg does not offer a complete curriculum, while the ETHZ offers only pharmacy. The low value for Basel is a statistical artifact since the data contain only the cost of preclinical training, while the cost of training in the hospitals is paid directly by the canton; this would more then double the total cost of medicine at the University of Basel. Note that the average costs are extremely high and, as the case of Fribourg demonstrates, are essentially due to the clinical training rather than to the basic education at the university.
4. *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 human and social sciences and indeed this is confirmed by the enrolment ratios.

8.3.6 Time Evolution

A full analysis of the evolution over time of these indicators would go well beyond the scope of this chapter. However, it is interesting to present some information on the evolution of the number of students and of the expenditures disaggregated by domain. As shown in Figure 8.5, not only has the number of students in the considered institutions grown strongly over the past 25 years, but this growth has also been essentially concentrated in human and social sciences, which doubled their total number of students.

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 from 1995 to 2003 since the financial statistics of universities was completely revised at the beginning of the 1990s and it is difficult to compare data for the preceding period (Lepori, 2005).

Considering that no Swiss university possesses a formula-based internal allocation mechanism and that almost everywhere historical considerations play an important role, 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, the increase is distributed to the disciplines proportionally to their share of the budget, irrespective of different evolutions in the number of students, while in the second, the increase is distributed according to the increase in the number of students.

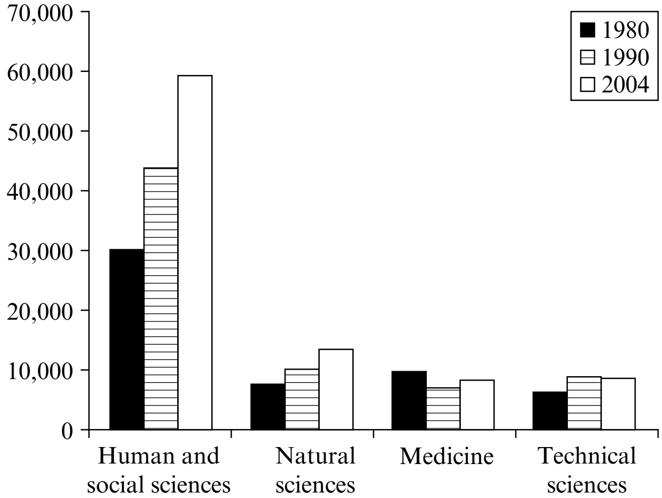

Figure 8.5 Evolution of number of undergraduate students by domain, 1980–2004

Table 8.5 shows the results for the five universities for which a meaningful comparison is possible. In three cases – Bern, Geneva and Zurich – it is evident that the budget increase was redistributed proportionally in the three domains, irrespective of diverging numbers of students. Lausanne is a rather special case since a large part of natural sciences was transferred to the EPFL, reducing strongly the number of students; even in this case, this domain more or less maintained its previous level of resources. The case of medicine is particularly striking since expenditures increased everywhere in spite of a decreasing number of students.

8.4 A VARIABLE COST FUNCTION FOR SWISS UNIVERSITIES

A growing 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 (for example, Nelson and Heverth, 1992; Koshal and Koshal, 1995), studies using a multi-output approach (for example, Koshal and Koshal, 1999; Koshal et al., 2001) and studies using a multi-output approach which also consider variables on research performance and/or quality (for example, Dundar and Lewis, 1995; Sav, 2004).[6]

Table 8.5 *Evolution of the expenditures and of the number of students per discipline, 1995–2003*

	All	Human and social sciences		Natural sciences		Medicine	
	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

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

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 carrying out research projects. Generally, a university is represented as a firm transforming three main inputs (physical capital, human capital and labour) 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 in the model should include as explanatory variables some indicators of the quality of these outputs. Unfortunately, precise information on quality is not always available.

The most relevant studies for our analysis are those by Koshal and Koshal (1999), and Sav (2004). Koshal and Koshal (1999) used a multi-product quadratic total cost function to analyse 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 and students per teacher as a 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 a 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 multi-product quadratic total cost function with the following variables: three teaching outputs (undergraduate students, graduate students, professional students), and grants received as a proxy for the research output. In addition, a dummy variable for the presence of a medical school and the price of labour are included in the cost model specification. Empirical results highlight the presence for a part of the institutions included in the analysis of ray (overall) 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 derived. 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 the number of undergraduate and graduate students masks large differences between components of the aggregated discipline (that is, medicine, and the social, natural and engineering sciences). Third, the measurement of research activities is difficult because of a 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 with 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; and (c) the definition of the outputs at the level of two aggregated disciplines.

For the specification of the cost model of 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 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 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 multi-product cost function for the Swiss universities may be written as:

$$VC = V(Y_{SS}, Y_{NSM}, P_L, C, Q, T), \tag{8.1}$$

where VC represents total variable cost, Y_{SS} is the number of students enrolled in a social science department and Y_{NSM} is the number of students in an engineering department, a natural science department or in the medicine faculty.[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 programme with doctoral courses. Therefore, the number of PhD students can also be considered a proxy for an input. PL is the price of labour, and C is the stock of capital. 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 university activity is a labour-intensive service and the quality of teaching also depends on the time allocated by professors and assistants to 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.

Following Koshal and Koshal (1999) and Koshal et al. (2001) we assume that variable cost (VC) of education output can be represented by a flexible cost quadratic function. Mayo (1984) and Baumol et al. (1988) recommend the use of a quadratic cost for estimating scale and scope economies for most types 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 (8.1) is:

$$\begin{aligned} VC = {} & \alpha_0 + \alpha_{SS} Y_{SS} + \alpha_{NSM} Y_{NSM} + \frac{1}{2}\alpha_{SS}(Y_{SS})^2 + \frac{1}{2}\alpha_{NSM}(Y_{NSM})^2 \\ & + \alpha_{SSNSM}(Y_{SS})(Y_{NSM}) + \alpha_C C + \alpha_{PL} P_L + \alpha_Q Q + \alpha_T T + \varepsilon. \end{aligned} \tag{8.2}$$

The properties of cost function (8.2) 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]

8.4.1 The Data

This study is based on a combined time-series and cross-sectional dataset for 12 universities operating over the 1994–2002 period in Switzerland (see Section 2 and Appendix 8A for a detailed description).

Variable cost is taken to be the sum of labour, energy and material costs. Outputs are measured in total number of students enrolled in human and social sciences departments and in natural science faculties or the medicine faculty. 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 staff.[13]

The capital stock is approximated by the area in square metres owned and operated by a university. Unfortunately no data are available which would allow us to calculate the capital stock using the capital inventory

Table 8.6 Descriptive statistics

	Mean	Std dev.	Median
Number of students: social sciences (Y_{SS})	4551	3886	4112
Number of students: natural sciences (Y_{NSM})	2510	2467	2085
Area in sq. m. (K)	121,941	91,142	114,030
Average labour price (P_L) in SFr per employee per year	109,675	12,513	109,760
Teaching staff ratio (R)	32.3	10.7	28.54

method. The input prices and variable costs were deflated to 2000 constant Swiss francs using the consumer price index. Table 8.6 lists means and standard deviations of the main variables.

8.4.2 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, that is, heterogeneity across units. The three most widely used approaches are: the ordinary least squares (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, for example, the coefficient of the capital stock included in (8.2). Moreover, the within variation of some variables is relatively small.[15] Thus, equation (8.2) is estimated using the GLS model.[16]

The estimated coefficients of the quadratic cost model (8.2) are presented in Table 8.7. The results are satisfying in so far as all first-order coefficients and some of the second-order coefficients are significant and carry the expected signs.

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 enrolled in the different disciplines will increase variable cost. As expected, the coefficient of the labour price is positive, implying that the cost function grows monotonically with 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

Table 8.7 Total cost parameter estimates (standard errors in parenthesis)

Parameters	
Constant	220,365,000***
	(46,818,700)
α_{QT1}	19,928.34***
	(5610.42)
α_{QT2}	29,324.52**
	(11,698.23)
α_{QT11}	1.894**
	(0.674)
α_{QT22}	0.288
	(3.906)
α_{QT12}	–0.892
	(2.022)
α_{K}	1708.253***
	(310)
α_{PL}	775.477**
	(291.058)
α_{T}	4,228,860***
	(929,463.706)
α_{QU}	–1,551,810**
	(602,917)

Note: *, **, *** significantly different from zero at the 90, 95 and 99% confidence levels.

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 labour price and by a general increase in research activities, which, as explained before, have not been considered in the model.

8.5 SHORT-RUN MARGINAL COST, ECONOMIES OF UTILIZATION AND SHORT-RUN ECONOMIES OF SCOPE

In Table 8.8, 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

Table 8.8 Marginal cost estimates (Swiss francs)

% of median output	MC_{SS} (Social sciences)	MC_{NCM} (natural sciences and medicine)
50	18,913	31,004
75	19,420	30,164
100	19,928	29,324
125	20,436	28,484
150	20,943	27,644

variables. This means that the values reported in Table 8.8 reflect the situation of a hypothetical HEI.

Moreover, the estimated cost depends strongly on the assumed discipline mix. An examination of the values reported in Table 8.8 suggests that, for all levels of output, the marginal cost of social science students is lower than that for natural science or medical students.

Note that these values are quite different from the amount of money paid to the university cantons by the cantons of origin of the students for the costs of their education (9500 SFr. per year for human and social sciences, 23,000 SFr. for natural, technical sciences and medicine, and 46,000 SFr. for medicine from the third 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:

$$ECU_{VC} = \frac{VC(Y_{SS}, Y_{NSM})}{MC_{SS}Y_{SS} + MC_{NSM}Y_{NSM}}, \tag{8.3}$$

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

We 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 both social science and natural science students are taught within the same university, it is possible that their production entails economies of scope. In the case of two outputs, following Panzar and

Table 8.9 Ray economies of capacity utilization and scope

% 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

Willig (1979) and Toft and Bjordal (1997), short-run economies of scope exist if:

$$TC(y_L, y_H) < TC(y_L, 0) + TC(0, y_H). \tag{8.4}$$

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:

$$ES = \frac{VC(Y_{SS}, 0) + VC(0, Y_{NSM}) - VC(Y_{SS}, Y_{NSM})}{VC(Y_{SS}, Y_{NSM})}. \tag{8.5}$$

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

In Table 8.9, we present the value of ray economies of capacity utilization and of 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 HEIs are characterized by excess capacity. Moreover, an examination of the values reported in the third column of Table 8.9 reveals that global economies of scope exist for the output range considered in this analysis ($ES > 0$). Therefore an unbundling of a multi-discipline into a single-discipline university leads to higher costs as the synergies in the joint production are no longer exploited.

8.6 DISCUSSION

The main goal of this study was to provide a first explorative analysis on the cost structure of Swiss HEIs using a number of simple indicators as well as the results obtained from the econometric estimation of a cost function. For this purpose, a panel data of all HEIs over the period between 1994 and

2002 has been analysed. To our knowledge, this is the first attempt to perform an analysis of the cost structure of these institutions. Moreover, the analysis has been performed at both the aggregate and the disaggregated levels, that is, 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 discipline groups are very large indeed, not only concerning cost levels, but also for other important indicators such as PhD degrees, enrolment ratios and staff structure. For these indicators, differences between discipline groups are actually larger than differences between universities. Note also that the significance of the average cost per student calculated for the whole university is limited, since for universities like Bern, Geneva, Lausanne or Zurich no group of disciplines has an average cost per student near to the average for the whole university. This means that comparisons of the cost between universities can easily be distorted if we do not consider the share of different domains covered by the HEIs. For instance, in universities with a full curriculum in medicine, this domain accounts for less than 10 per cent of the undergraduate students, but for more than 50 per cent 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 human and social sciences, as the number of students 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 enrol more staff for duties such as student support, tutoring, exams and so on. However, in the Swiss model, teaching assistants are normally at the same time PhD students and thus the volume of research increases automatically with the increasing number of students as indicated by the number of PhD degrees per undergraduate student.

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 for a stronger specialization between institutions or curricula in research intensity. Note that the number of students is very low with an average for natural sciences, medicine and technical sciences of only 2500 students; in natural sciences all universities except the ETHZ have fewer than 2000 students, while the largest medicine department at the University of Zurich has 2000 students, with costs higher than for the 15,000 students in the whole of human and social 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 there has to be research activity, meaning a research team of minimal size, irrespective of the number of students. Moreover, these domains have a much higher share of external funds than human and social sciences; since in the Swiss context most third-party funds provide salaries only 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 between domains in the face of larger student numbers, which increased much more strongly in human and social sciences than in the other domains.

In the second half of the chapter we provided an empirical analysis on the cost structure of 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 from 1994 to 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 HEIs are characterized by excess capacity and that an unbundling of a multi-discipline into a 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 a first explorative econometric analysis of the cost structure of 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 an indicator of the research activities as an explanatory variable. Given these problems, the empirical results reported in this chapter should be considered with caution.

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

NOTES

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1. For a discussion on the difference between simple and econometric-based performance indicators, see Farsi and Filippini (2006).
2. For a discussion on 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).
3. The interdisciplinary domain is very small.
4. Note that the productivity analysis of Swiss HEIs is beyond the goals of this chapter. Moreover, in order to construct any measure of productivity, one needs to define relevant measures of outputs and inputs. In the case of Swiss universities, the lack of information on the research performance creates some problems in doing a productivity analysis.
5. The data from the new analytical accounting system of the Swiss universities could bring some improvements especially concerning the breakdown between education and research expenditures; first data for 2004 have recently been published (Conférence Universitaire Suisse, 2006).
6. In the literature there are 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.
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 a 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 funds. Moreover, data on publications are not available for all disciplines. For this reason we decided to use only two outputs related to the teaching activities.
9. The data considered in this study refer to a period in which the Swiss university system did not distinguish between Bachelor and Master studies. For this reason, we employed the total number of graduate and undergraduate students as output indicators.
10. One of the shortcomings of this functional form is the impossibility of imposing the linear homogeneity condition on the parameters. However, for the analysis of the economies of scope, this function possesses clear advantages in comparison with other functional forms. For a discussion on the advantages and disadvantages of this functional form, see Chambers (1988). However, due to the fact that in this study we are considering only one factor price, 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 assistants and administrative staff). 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.
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 (2003).

15. For a discussion on this issue, see Farsi et al. (2005a).
16. In order to decide between the OLS and the GLS models, we employed the Lagrange multiplier test. The result of this test shows that the GLS should be preferred to the OLS.
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 in the capital stock would lead to an increase in 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 coefficient between the proxy for the capital stock and the outputs is very high.

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APPENDIX 8A VARIABLES, DATA SOURCES AND METHODOLOGICAL COMMENTS

Table 8A.1 Variables used and methodological comments

Variable	Definition and coverage
Undergraduate students	Students in the basic university curriculum (diploma: 4y; medicine: 6y). Since 2000 some universities introduced the Bologna model: this category also comprises 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 programmes 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 (5 years); excludes 3-yr 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 into XVIII personnel categories, which are then grouped into four main categories: 1. professors: ordinary, extraordinary and assistant professors; 2. senior academic staff, mainly with teaching duties; 3. junior academic staff, including research and teaching assistants (most of the PhD students are in this group); and 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

Table 8A.1 (continued)

Variable	Definition and coverage
Expenditures	University expenditures in SIUS cover only the following categories: • all staff costs, including social charges; and • functioning costs (travel, consumables, maintenance) Expenditure costs also include some costs which would be considered as part of capital costs, such as amortisements and rents; however, data show that these costs are low (max. 5% of total expenditures). Expenditures do not include capital costs, or investments, which are normally accounted separately (or 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 UNIBS to 31% for UNISI), probably reflecting different accounting methods, when considering data for single-activity domains, we distribute these central costs proportionally for each expenditure category (thus separately for each personnel category and for functioning 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 discipline group). We use the data for 1999 (the latest data available) since we do not expect that floor space is changing rapidly (except for UNISI which was founded only in 1996). More recent data will available shortly Source: SFSO
ISI publications	ISI publication 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 1981–85 to 1998–2002; the number of publications by subdomain is available only as a mean for the years 1997–2001. There are no data on the three smallest universities Source: CEST 2003

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