MIT and ETH Zürich: Structures and Cultures Juxtaposed

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Center for Science and Technology Studies
Zentrum für Wissenschafts- und Technologiestudien
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Editor's Preface

Motives of the study

The objective of the present study on the *Massachusetts Institute of Technology (MIT)* and the *Swiss Federal Institute of Technology Zurich (ETHZ)* is best defined in the words of the authors themselves:

> "What we do want is to compare two leading institutions of higher education – in order to learn."[1]

The clearly stated purpose of this comparative case study leaves no doubt about its immediate intrinsic interest: to know more about and to better understand the functioning of two renowned institutions of higher education and research. Despite the straightforward definition as far as the topic of the study is concerned, such an approach naturally raises further questions. The reason for this is, that *what* you learn quite certainly also depends on *where* you are looking, but also on the question of *why* you are focusing on the specific cases or "learning objects" selected. Thus, a general question any case study has to face is what the selected objects of study are standing for.

Why compare MIT and ETHZ, what are the selection criteria and in what context is such a comparison to be placed? A first indication to answer questions like these is again given by the authors of the present study. As the reader is asserted right at the outset, this

> "juxtaposition will not be symmetrical, however: MIT shall be used as a benchmark against which to assess the performance of ETHZ (and not vice versa)".[2]

With this, the motives to engage in the study are in line with the more general aims of the commissioner of the present report, the Center for Science and Technology Studies (CEST). One of the central missions of this institution is to analyse and monitor the standing and the development of Swiss research in an international comparison. As a consequence and besides other motives and interests to be outlined by the authors themselves, the present study can also be placed in the context of some recent work and results published by CEST.

Context of the study

Although recent empirical studies[3] offer evidence that traditional comparative advantages and strengths of Switzerland's research system are indeed more and more challenged by an increasingly competitive environment at the international level, the country's overall performance by generally accepted international standards is (still) indicative of a highly developed research landscape. Switzerland accounted for 1,2% of the worldwide scientific production in 1994-1999 as far as publications in ISI-covered international journals are concerned.[4] With this it ranks 12th amongst all countries and belongs to a group of middle-sized scientific nations (together with the Netherlands, Australia, Spain and Sweden). These countries are behind the large-sized G7-countries but still in front of all other OECD-nations, each of them accounting for less than 1% of the worldwide scientific pub-

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[1] See this Report, p. 6.
[2] See Report, p. 7.
[3] See CEST 2001/12: *La place scientifique Suisse entre compétition et coopération 1994-1999. Une contribution à l' »Etat de la recherche suisse » et à la « Topographie de la place scientifique suisse ».*
[4] ISI-indexed journals cover all journals processed by the Institute for Scientific Information (ISI) for its series of *Citation Indexes* and the *Web of Science*.

lishing activity. Findings further indicate that Switzerland ranks 2nd not only when measured by papers per inhabitant (behind Sweden), but also as far as the scientific impact of its articles measured by their average relative citation index is concerned (behind USA).

For scientists working at the international research fronts, scientific recognition and excellence has always been of crucial importance. However, the challenge of increasing international scientific competition has also to be faced at the institutional level. As a matter of fact, achieving and maintaining scientific competitiveness has also become a strategic goal of many research institutions. In Switzerland, some 25 institutions alone are accounting for about 90% of this country's publishing activity. Of these institutional main producers of scientific papers, 9 are research-oriented universities[5] accounting together for almost 70% of the Swiss articles covered by ISI-databases.

As Burton R. CLARK[6] and others have argued, the term "research university" is now an appropriate label for the leading universities in most developed countries. In any disciplinary area and scientific field, academic staff at research universities is expected to produce knowledge, use the most recent research results in their teaching, and train students to conduct research.

Cross-country comparisons and the elaboration of average indicators of research performance are appropriate tools for a general assessment of the position of a nation's research system, especially if monitored over time. But if we want to know more on the competitiveness of the research system of Switzerland and its driving forces, the research institutions, more pertinent tools than indicators of general national performance are needed.

How competitive is the university research system of Switzerland and where are its "centers of competence"[7]? Questions like these are not only crucial for a more differentiated assessment of sectoral or institutional performance, but to overall research performance as well. Clearly such questions offer further evidence of the need to look at the Swiss (university) research system in its component parts. As already mentioned, Switzerland still ranks 2nd as far as overall performance of the research system, as measured by the average relative citation index, is concerned. But it ranks only 4th as to the performance of its university research sector. Facts and comparisons like these illustrate that we should extend analyses at a sectoral and institutional level. From this we can learn more about the real level of research performance and variations across the research system than from overall averages alone.

A new tool developed by CEST, labeled *The Worldwide Champions League of Research Institutions,* offers important new and complementary opportunities to identify and compare research sectors at a cross-country level as well as for monitoring and comparing profiles of performance at the level of research institutions.[8] For this aim CEST has identified nearly 1000 institutions with an outstanding research record in at least one area of scientific research, often in several and sometimes in a large range of research areas. Each of these institutions has, first, managed to attain or sustain over the years significant quantities of papers published in ISI-indexed international journals in one or in various specific fields of research. Secondly, and simultaneously in one or various of these fields,

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[5] Seven cantonal universities (Basel, Berne, Fribourg, Genève, Lausanne, Neuchâtel and Zürich) and the two Swiss Federal Institutes of Technology in Lausanne (EPFL) and in Zürich (ETHZ).

[6] Burton R. Clark, *The Research Foundations of Graduate Education: Germany, Britain, France, United States, Japan,* Berkeley: University of California Press, 1993.

[7] "Centers of Excellence" is another, somewhat more value-laden term for this.

[8] See CEST 2001/11: *Die Schweiz und die weltweite Champions League der Forschungsinstitutionen 1994-1999. Ein Beitrag zu einem internationalen Benchmarking. Konzept und erste Resultate (Zwischenbericht).*

all of these institutions have also produced papers with a worldwide impact significantly above average as defined by citation scores.[9]

More detailed studies[10] of these "world class" research institutions based on advanced bibliometric methods have shown that the majority of these institutions – almost 600 or about 60% – are representatives of the university sector. Given the overall bibliometric record of the USA it may not be of much surprise that this country is not only dominating the *Champions League* of research as a whole, but also the performance of the worldwide university sector and its representatives qualifying for the *Champions League*. What may be more striking is, for example, the fact that the domination of the somewhat more than 200 US universities represented in the *Champions League* is more substantial than the simple number of its institutions or than overall and traditionally used bibliometric cross-country comparisons would suggest.

The striking differences as far as the role of US research universities (when compared to universities elsewhere) is concerned and as revealed by the analyses of the *Champions League* of research institutions leads the authors of the present study to the conclusion, that

> "there appears to exist a performance gradient which separates US research universities from those of the rest of the world."[11]

And indeed, there is evidence supporting statements like this. To take just one parameter out of several others – the "influence" of the US-universities as defined by the number of publications in those fields where they have a substantial amount of publications qualifying for the Champions League (that is by means of a relative average impact of these field-specific publication-sets being significantly above world average): Only 6 out of the top 50 most influential universities worldwide are non-US universities.[12]

This finding is also significant for similarities as well as for differences between MIT and ETHZ. Both are belonging to the top 50 of the most influential institutions in the *Champions League* as just defined. With this, ETHZ figures under the "top of the tops" and is one of the 6 non-US universities mentioned of this group. Moreover, ETHZ is the only university in these top 50 not based in an Anglo-Saxon country and the only one located in continental Europe (the other 5 non-US universities being located in the United Kingdom and

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[9] From an institutional point of view, "scientific excellence" may require more than the occasional production of "hot papers", i.e. the production of some very highly cited papers. Hence, the concept of the *Champions League of Research* introduced by CEST takes into account the average performance of the whole publication record of an institution in a specific field of research, where a significant quantity of publications over a time-period of several years has been produced by the scholars of a candidate-institution for the *Champions League*. Such an approach favours not just the "soloists", but the "orchestra" as a whole, to paraphrase nobelist Rolf M. ZINKERNAGEL, who used to say, that the Nobel prize "rewards the soloists, instead of the orchestras" (Der Bund, October 5th, 2001). With this, the comparatively robust statistical approach used by CEST differs not only from popular measures to identify single "citation stars", but also from the approach used in a recently published EC study. This study is not only making no distinction between fields of research, but uses only the number of publications across all fields in the top 1% cited worldwide; see European Commission, *Progress Report on Benchmarking of National Policies*, Brussels 2001.
To the complementary relationship between quantity and quality see also Jürgen MITTELSTRASS, Exzellenz und Mittelmass, in *Gegenworte*, 5.Heft, Frühling 2000, p. 25: "Es ist das breite Mittelmass, das auch in der Wissenschaft das Gewohnte ist, und es ist die breite Qualität, die aus dem Mittelmass wächst, die uns in der Wissenschaft am Ende auch die Exzellenz beschert."

[10] See CEST 2002/6: *La Suisse et la « Champions League » internationale des institutions de recherche 1994-1999. Contribution au benchmarking international (Rapport final).*

[11] See Report, p. 150; see also p. 14.

[12] See CEST 2002/6, op.cit.

in Canada).[13] On the other hand and compared to MIT on the same scale, the total number of publications in the fields qualifying for the Champions League differs in favour of MIT by a factor of almost 3.

As shown elsewhere, differences of performance of research institutions can in part be explained by size or mass effects.[14] However, even if in general there seems to exist a positive relationship between size as measured by the total publication output of an institution and citation-impact of these publications, it is difficult to identify any clear threshold above which performance suddenly changes. Rather, the relationship between size and performance seems to be a continuous one. And large size may not always be a necessary nor a sufficient condition of high-level performance. As a consequence, relatively small but specialized institutions performing selectively in a restricted number of research fields are not excluded from participating in the *Champions League*. However, that such a strategy may turn out to be a more risky business than if the research portfolio of an institution is based on a relatively broad and well balanced range of scientific fields is just another point which would need further investigation.

It would be too short-sighted to reduce differences between US universities and, say, European or Swiss universities to mass effects alone or to a “publish-or-perish-syndrome” often assumed to be more accentuated in the USA than elsewhere. Research institutions in general and research universities in particular are by nature multifunctional entities, characterized by a variety of (research) missions, differing by their resources and capabilities as well as by the characteristics of their (research) outputs.

A substantial publication output in peer reviewed international journals, a significant impact of these publications in the scientific community or, to take other records, prestigious science prizes and appointments from international committees (the Nobel prize just being the most renowned of these) are certainly important and widely accepted indicators to identify “centers of competence”. But we fully agree with the authors of the present study, that “bibliometric measures or Nobel prizes clearly will not tell the whole story”.[15]

Complex phenomena require multiple methods and approaches to identify and assess possible factors playing a role in explaining both differences and similarities of two institutions like MIT and ETHZ. Hence, fully fledged quantitative studies and large scale benchmarking at institutional levels need to be complemented by other methods and information sources, including e.g. peer review. These are just some of the main reasons for the present study to compare peer institutions – and to juxtapose MIT and ETHZ. As a consequence, and in order to arrive at a more comprehensive and balanced evidence-based assessment, case studies based on in-depth analyses like that presented here and large scale quantitative analyses underlying the concept of the *International Champions League of Research Institutions* are complementary and ultimately just the well-known two sides of the same coin.

Results of the study

This preface is not the place to summarize such a rich and useful piece of work on MIT and ETHZ as that presented by the three authors. To cut a much longer story short, the study represents an important step towards identifying and explaining similarities and dif-

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[13] On ETHZ see also CEST 2002/1: *Les institutions du domaine des Ecoles polytechniques fédérales. Profils de recherche et comparaisons internationales. Indicateurs bibliométriques pour les années 1994-1999.*

[14] See CEST 2002/10: *Entre effet de masse et spécialisation: état des lieux de la recherche des Hautes écoles suisses. Rapport d’une étude de consultance basée sur une analyse bibliométrique.*

[15] See Report, p. 148.

ferences not only between MIT and ETHZ, but also between US and European research universities. Although the two institutions compared are analysed in a broad systemic and cultural context, a whole range of specific factors which characterize both institutions are documented and analysed. All factors in combination seem to play a role in explaining institutional performance. But according to the authors, one factor clearly stands out: "morphological" or structural characteristics:

> "leading, high performing research universities tend to have comparatively low student-faculty and low staff-faculty ratios".[16]

And here, the authors identify clear comparative advantages in favour of MIT and other leading US research universities. But the authors proceed in linking this "Production-Morphology Nexus" to cultural differences which separate not only individual institutions as such, but national higher education research systems as well.

As stated, this preface is not intended to summarize the results of the study, nor is it intended to summarize or even to close a lively discussion which already has been initiated by the study itself. However, one thing already seems clear: the study not only succeeds in shedding more light on substantial issues related to performance differentials of research universities at the institutional as well as on more systemic levels. In fact, and as intended by the authors themselves, it has already – and will hopefully continue in doing so – provoked further questions and debates in order to develop further study and a deeper understanding of the complex issues at hand. One such question, for example, might be to ask whether scholars around the world, in different cultural and political contexts and in universities are motivated to conduct and publish research by the same incentives. Such questions could also help to link specific institutional and structural issues to broader and more systemic contexts and to show how the different levels interact.

According to one of the experts commenting on the present study, nobelist Kurt WÜTHRICH, differences in incentive structures are not to be neglected when he is saying, that "the US system has the advantage of catering more flexibly to the needs and ambitions of the individual principal investigators. The advantage of the ETHZ system is to be seen primarily in the (rather rare) cases where long-term projects are pursued, which might have to be abandoned for lack of funding in the US system." Thus, to this commentator it seems clear, that the "key difference is that the funding [in the US system] has to come from outside sources."[17]

The authors of the present study have not only succeeded in shedding light on important issues and in stimulating a continuing and hopefully fruitful debate, they have also been successful in what they consciously have avoided. One of these deliberate "non-actions" was to avoid painting a glorious picture of a particular model, here the US higher education model. The point was certainly not to prove the superiority of one model, one culture, or of one nation over others, but to understand – i.e. learning-by-comparing – the functioning of institutions of higher education and to find ways to improve their effectiveness, in this context obviously the effectiveness of Swiss research universities.

There are other possible pitfalls which the authors have consciously avoided. One of them particularly worth noting here is that they did not fall into the trap of what Rémi BARRÉ has called "the trap of simplification nonsense" by producing "nonsense productivity indicators".[18] This trap refers to the temptation to establish too direct a linkage between indi-

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[16] See Report, p. 15.
[17] See Report, p. 144.
[18] Rémi BARRÉ, Sense and nonsense of S&T productivity indicators, in *Science and Public Policy*, 28(4), 2001, pp. 259-266.

cators and productivity assessments.[19] Although very appealing, this is a risky business, stemming from needs to have, or even simplistically use, crude measures of “efficiency”. However, such measures are based on cognitively weak and often mechanistically applied concepts. The result is that not only may some comparatively meaningful information on productivity and effectiveness be lost (e.g. when comparing countries or institutions), but that the potentially useful content and information of, say, input indicators on the one hand, and output indicators on the other hand cannot be discussed and assessed properly. As the authors point out, there is, first, the problem to have comparable data sets and indicators as well as a necessary, but lacking “1-1 correspondence to tie output to input”.[20] But the authors point to numerous other open questions, specifically, and with an eye on funding agencies, to a range of dangers and unintended side-effects. They all together “prevent a water-tight allocation of resources” based on too mechanistically implemented funding formulae.[21]

To be sure, indicators will provide one of the cornerstones of an informed and pluralistic debate on strengths and weaknesses, on opportunities and threats. Thus, indicators are not to be considered as a final result to be accepted or rejected, but as an entry point for discussion in a wider network involving various actors (e.g. scientists and decision-makers).[22] Benchmarking as a “no-nonsense policy instrument” combined with a wise use of indicators implies “a sequence of quantitative and qualitative analysis phases, each one feeding from the previous and into the next, in a virtuous circle of comparative understanding.”[23]

Fortunately, such an exercise is exactly what the authors had in mind when they started to independently analyse quantitative and qualitative material and then engaged in, actively supported by CEST, an open and pluralistic dialogue with experts from both sides of the Atlantic. These were experts familiar with different aspects of the topic of the study, many of them either with MIT or ETHZ or with both of them, others also with the US and/or the Swiss and European higher education research systems, and still others also with institutional research in general. Hence, and in line with what benchmarking is about, the study provides a starting point not only for meaningful comparison and understanding, but also for interactions between all those concerned with continuously improving science and research as well as those who might study its functioning further.

Acknowledgements

There is no doubt, that a study like that presented here could not have been realized without competent authors having a long experience with MIT and ETH-Zürich and their institutional environment, as well as with the developments in the study of higher education systems and in institutional research. CEST would like to thank, first, the authors,

[19] The danger is immediately seen, as stated by the authors, if indices such as ‘graduates per teacher’ or ‘costs per student’ are computed (see Report, p. 21). However, as BARRÉ (op.cit.) and others have argued, the danger would even be accentuated with respect to (university) R&D outputs and (non-) comparative measures like e.g. ‘publications per dollar’ or ‘citations per researcher’. The problems arise already when nations are compared, but become more serious the more the units of comparison are further disaggregated.

[20] See Report, p. 149.

[21] About these points see this Report, sections “Input-Output Modeling of Universities” and “Efficiency, Effectiveness and Productivity”, pp. 24-26.
BARRÉ, op. cit., p. 264 goes on to state, that this “lack of content would lead to difficulties in enrolling the relevant actors who would have difficulty positioning themselves meaningfully into the picture, and as a result policies are likely to be unsuccessful.”

[22] To the concept of benchmarking as a joint strategic monitoring exercise and a joint learning process, see also CEST 2001/11, op. cit., pp. 24-28.

[23] BARRÉ, op. cit., pp. 264-265.

Marcel HERBST, Urs HUGENTOBLER, and Lydia SNOVER, for their effort in developing the basic theses of the study and to present corresponding evidence, all this with the rather short time frame available and accompanied by a continuous readiness to discuss and reflect the issues with other experts and on many occasions.

CEST also wants to thank all the experts having contributed to this report by discussing the findings and conclusions of the authors, either at a special workshop on the report which took place in Zürich on September 13th, 2002,[24] and/or by their written or oral contributions to this debate.[25] Special thanks go to the Executive Director of the Association for Institutional Research (AIR), Terrence RUSSELL, who chaired the workshop. Last but not least, CEST is grateful to ETHZ for having hosted this workshop.

Berne, October 2002 François Da Pozzo, CEST

[24] The following persons participated at the workshop (in brackets: present or former institutional affiliation):
Authors (see also Appendix E.1): Marcel Herbst (4mation/4mat, formerly ETHZ), Urs Hugentobler (ETHZ), Lydia Snover (MIT).
Experts (see also Appendix E.2): Hanspeter Eichenberger (IBM-General Electric), Susan Frost (Emory University), Willi Gujer (ETHZ/EAWAG), Hans-Jakob Lüthi (ETHZ), George Moschytz (ETHZ), Werner Oechslin (ETHZ), Sotiris Pratsinis (ETHZ), Terrence Russell (Florida State University and AIR), Daniel Spreng (ETHZ), Wendelin Stark (ETHZ), Ulrich Suter (ETHZ).
CEST: François Da Pozzo, Anne Roulin Perriard, Markus von Ins.
[25] The contributions and the names of the authors, who permitted that their comments are published, are contained in chapter 9 of the present report.

Contents

Kurzfassung

Vom Gefühl des Mangelnden gehen alle Verbesserungen aus.

Friedrich Schleiermacher [238]

Der vorliegende Bericht vergleicht zwei führende technische Universitäten, das Massachusetts Institute of Technology (MIT) und die Eidgenössische Technische Hochschule in Zürich (ETHZ). Dieser Vergleich erfolgt vor dem Hintergrund der entsprechenden akademischen Kulturen, in welche die beiden Institutionen eingebettet sind. Entsprechend der Zielsetzung des Berichtes ist der Vergleich aus einer schweizerischen Perspektive heraus geschrieben, indem die ETHZ sich — vergleichend — am MIT orientiert, und nicht umgekehrt. Der Vergleich ist daher nicht symmetrisch, nicht ausbalanciert. Der Bericht stellt einen Versuch dar, die üblichen Ländervergleiche der Forschungsleistungen auf die institutionelle Ebene zu übertragen und die Institution in ihrer Funktion ganzheitlicher zu erfassen. Die wesentlichen Ergebnisse der vorliegenden Recherche sind die folgenden:

Forschungsoutput Mehrere Indizien sprechen dafür, dass zwischen Europa und den Vereinigten Staaten (US) ein Gefälle bezüglich Forschungsleistungen besteht: Institutionen der US, verglichen mit entsprechenden europäischen Institutionen, scheinen leistungsfähiger zu sein. Dieses Gefälle zeigt sich auch beim Vergleich MIT und ETHZ.

Forschung und Lehre Im Rahmen der modernen, forschungsorientierten Universität ist die Forschung mit der Lehre gekoppelt. Die Forschung kann als Indikator der Qualität der Lehre herangezogen werden.

Leistung und Morphologie Indizien sprechen auch dafür, dass die Leistung einer Universität mit ihrer Morphologie, mit ihrem strukturellen Aufbau in Zusammenhang gebracht werden kann. An führenden nordamerikanischen Universitäten stehen den Studierenden mehr Professoren zur Verfügung (als in Europa), und die Forschungsgruppen sind kleiner. Die Vermutung liegt nahe, dass zumindest Teile der Leistungsdifferenzen, die im Bereich der Forschung festgestellt werden können, durch diese morphologischen Differenzen erklärt werden können. Die Vermutung liegt auch nahe, dass die Morphologie für die Qualität der Lehre bestimmend ist.

Kulturelle Unterschiede Die Unterschiede im morphologischen (organisatorischen bzw. strukturellen) Aufbau der Institutionen sind weitgehend kulturell bestimmt. Diese Kulturen sind ihrerseits wiederum national geprägt — trotz der weitgehend internationalen Ausrichtung der Forschung selbst — und widersetzen sich eher einem kontinuierlichen Wandel, wie wir ihn z.B. von der Industrie her kennen. Dadurch entsteht die Gefahr, dass sich die Hochschulen nicht genügend an die äusseren Umstände (von Gesellschaft und Wirtschaft) anpassen — und diese Umstände ihrerseits auch nicht genügend prägen.

Konfliktpotential Auf dem Hintergrund der Zurückhaltung, mit der Hochschulen dem Wandel begegnen und den Forderungen, die den Hochschulen seitens der Gesellschaft gegenüber gestellt werden, entwickelt sich ein Konfliktpotential, das der Hochschule als Institution abträglich ist: die Hochschule wird oft nicht genügend alimentiert und ihre Autonomie ist eingeschränkt.

MIT und ETHZ: Gemeinsamkeiten Der Vergleich von MIT und ETHZ ist naheliegend: beide Institutionen sind aus ähnlichen Motiven heraus gegründet worden, sie haben eine ähnliche inhaltliche Ausrichtung und sind zudem fast gleich gross (bezüglich Studierenden wie Personal).

MIT und ETHZ: Doktorate Betrachten wir die Abschlüsse auf der Stufe der Doktorate (als Leistungsindikatoren), so zeichnen sich beide Hochschulen als führende Institutionen aus. Die ETHZ zeigt sich bezüglich dieses Leistungsindikators als dem MIT gleichwertig.

MIT und ETHZ: Forschungsoutput Was wir eingangs erwähnten lässt sich jedoch auch beim direkten Vergleich zwischen MIT und ETHZ nachweisen: MIT erscheint bezüglich den Forschungsleistungen effektiver: Zahl und Rezeption der Publikationen sind oft wesentlich höher als jene der ETHZ.

MIT und ETHZ: Institutionelle Unterschiede Faktoren, welche als mögliche Ursachen für Leistungsunterschiede herangezogen werden können, lassen sich ausweisen: MIT hat wesentlich mehr Professuren als die ETHZ, und dementsprechend eine bessere Betreuung der Studierenden und kleinere Forschungsgruppen. MIT erscheint weniger fragmentiert, hat eine breitere Ressourcenbasis und wird untenehmerischer geführt.

Konklusionen Institutionelle Vergleiche sind weiterzuführen und zu verfeinern. Eine Reihe von Aufgaben stellen sich, die im Zuge künftiger Studien zu vertiefen und zu recherchieren sein werden: Erhöhung der Qualität und Leistungsfähigkeit (Effektivität) der schweizerischen Hochschulen; Überprüfung der Funktion von Förderinstitionen und Form der Alimentierung der Forschung; Umsetzung der Bologna-Deklaration; Stärkung der Autonomie der Institutionen und Professionalisierung von Führung und Administration.

Foreword

The old people in a new world, the new people made out of the old, that is the story that I mean to tell, for that is what really is and what I really know.

Gertrude Stein [210]

The present study is a juxtaposition, a comparative analysis, of two leading research universities: the Massachusetts Institute of Technology (MIT) and the Swiss Federal Institute of Technology (ETH Zürich). The motive to conduct such a study was fueled by the observation that cultures of higher education are quite distinct and exhibit a strong national bent. This distinctiveness alone would not have prompted the urge to embark on comparative analyses were it not for the hypothesis that institutions of marked distinctiveness — but similar mission — are hardly equally effective. While the dynamics of change and competition imply disequilibration and diversity, there are also strong corrective tendencies which work in the opposite direction.

Comparative Study of Individual Institutions The observation that higher education institutions have strong national roots, despite international research collaborations, and that individual institutions — intuitively assessed — are characterized by differing performance levels has prompted an interest to study individual institutions in a comparative fashion. This position was buttressed by a second observation concerning the restricted significance of science productivity measures as they pertain to nations [239, 170, 33], particularly to small nations such as Switzerland. With this focus, two institutions where chosen which are prominent in their respective environment: one in the US, naturally imbued by the anglo-saxon culture of higher education, and the other on the European continent with a certain leaning to what is referred to as the heritage of von Humboldt [231].

Cultures of higher education are quite distinct and exhibit a strong national bent.

The interest in comparative analyses of institutions of higher education actually dates back to the early 1990s when two of the authors, Lydia Snover and Marcel Herbst, met with Bob Simha [205] at the annual forum of the Association for Institutional Research (AIR) in San Francisco. It was decided then to launch such a comparative study, but the enterprise proved to be too ambitious [151]: the study covered eight institutions[1] and the information base was far less developed as it is now. In the intervening years the cooperation and discussions between administrators of MIT and ETH Zürich continued: representatives of the two institutions met at professional meetings, served together on forum committees, chaired sessions, delivered papers, and generally exchanged information. When Rector Osterwalder of ETH Zürich decided to survey alumni, the survey form designed by the former Head of Information Management, Jean-Claude Stettler, was molded after the corresponding survey of MIT. And when Urs Hugentobler, the new Head of Information Management at ETH Zürich expressed an interest to participate in the present study, the team of authors was complete.

Institutions of similar mission but markedly different internal organization are unlikely equally effective.

We had stated our hunch that institutions of similar mission but markedly different internal organization are unlikely equally effective. The hunch is based on experiences in manufacturing: new and successful production processes replace or marginalize old processes. When the American automotive industry realized that the Japanese industry was in a position to produce cars of better quality and place them on the market at lower prices, a investigation and adaptation process was initiated lest the domestic US automotive industry would vanish [218]. In the field of higher education this adaptation process is far less ingrained, perhaps because the need for change is felt less urgently. Nonetheless, in both sectors — in manufacturing as in public sector industries like higher education — comparative analyses have a long history and frequently employ similar methodologies [100].

Benchmarking In recent decades comparative analyses have been popularized under the title of 'benchmarking', an activity which is seen as part of the quality movement [111] and as "learning how to learn from others" [174]. Benchmarking is seen as a

> "[…] process of improving performance by continuously identifying, understanding and adapting outstanding practices and processes found inside and outside the organization." [4]

Whereas the present comparative analysis is inspired by an attempt to learn from others, it may not qualify as a true benchmarking study — or only as one of its initial phases. Too numerous are the aspects about which we do not know much and too complex the system we are trying to study. In the field of higher education, the connection between output measures on the one hand and input or process measures on the other is ill understood and, consequently, outstanding practices and processes are difficult to identify. However, if we adopt the definition that

> "[b]enchmarking is the process of continually comparing the performance of an organisation (or part of an organisation) against the performances of others,

[1] MIT; University of Texas at Austin; University of Cambridge; Imperial College of Science, Technology and Medicine; TU Darmstadt; Universität Karlsruhe; Chalmers University of Technology; ETH Zürich.

> with the intention of using the outcomes of comparison for the purposes of improvement," [241]

we may have no discrepancy between this notion of benchmarking and what is being attempted here.

Loosely speaking, the present study falls into the realms of a sociology of science [153] or, better yet, onto the intersection of a sociology of science and institutional research. Institutional research is the professional home of the authors of this study, because they work — or worked — as administrators within their respective institutions. With the onset of the 'Golden Age' of higher education in the post World War II era [77], institutional research came into being and spread from its origins in the US to the UK and continental Europe, particularly to the Netherlands and the Scandinavian countries. Despite its success, institutional research has failed to focus on issues of effectiveness and productivity, and cross-cultural, inter-institutional comparisons — or benchmarkings — have been rare [125]. One notable exception in the national, inter-institutional context are the excellent studies commissioned by the US National Research Council [164].

Sociology and Institutional Research The failure of institutional research to properly address issues of effectiveness and productivity is all the more perplexing in the context of the recent, government inspired, focus on performance-based budgeting [110, 32]. The almost uniform rejection of performance-based budgeting measures among administrators and institutional researchers is perhaps based on reasonable fears that reductionistic approaches will not be appropriate to capture the complexity of higher education institutions and, hence, should not be employed in their management [193]. But if institutional research fails to focus on issues of effectiveness and productivity, institutions themselves, in exercising their autonomy, will be unable to redirect their own institutional environment and will be unable to manage change.

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While institutional research, as a topically focused science, missed the opportunity to center on performance issues, the academic field of a sociology of science missed the opportunity as well. The problem of this sector of sociology may be due to the amorphous and broad nature of the field spanning macro-social — or societal — aspects up to portions of a philosophy of science. Sociology, and with it the sociology of science, is a field with a prodigious past and many outstanding contributions. But its development has taken the field to other shores. In his preface to his major analysis of the German university, HELMUT SCHELSKY observed in the early 1960s [190] (p. 8) that:

> "Es ist auffällig, wie sehr sich das deutsche wissenschaftliche Denken bisher dem Gesichtspunkt der soziologischen Analyse der Universität verschlossen hat; während zum Beispiel in den [USA] seit Generationen [...] unbekümmert die

> sozialen Zusammenhänge der Universität soziologisch überprüft werden, zerfällt die deutsche wissenschaftliche Erörterung der Universität in pädagogisch-philosophische Ideenanalyse und hochschulrechtliche Untersuchungen, also beides unmittelbar normative Betrachtungsweisen, einerseits und in unmittelbar pragmatische, die sozialen Tatsachen meist sehr subjektiv in Betracht ziehende Universitätsplanungen andererseits; eine analytische Soziologie der Universität gibt es bei uns nur in Ansätzen."

To a large degree, this analysis of the situation is still valid today. What SCHELSKY did not foresee, however, is a discontinuation of MERTON's school, at least within the sociology of science (and not within institutional research). STEPHEN COLE observes [48] (pp. 4-5) that,

> "[up] until the 1970s sociologist of science [...] studied the internal social organization of the scientific community and paid very little attention to the cognitive content of science. The papers and books produced by scientists remained [...] a 'black box'.
>
> This situation changed rapidly in the 1970s. Influenced by the revolution which had occurred in the history and philosophy of science, sociologist concentrated their attention on explaining the content of ideas. Although both American and European sociologist studied this problem, the work of the latter became increasingly important. The approach to the sociology of science dominated today [...] is now commonly referred to as 'social constructivism'."

What we try to do in the present study, hence, might be considered old fashioned by today's paradigms of sociology of science. But as members of the institutional research community, as representatives of a topical science and as skeptics [208], our focus is more applied. There are themes which are not properly addressed within today's sociology of science, despite its relevance — and despite truly excellent precursor studies [12] which guide our own investigations[2].

Biases Having commented on social constructivism, we must also state that the attempt to embark on a cross-cultural, inter-institutional comparative analysis raises fears to stumble over chauvinistic sensibilities or fall into traps of one's own prejudices. Both dangers are difficult to circumvent. Chauvinistic sensibilities abound here and abroad. It is likely that European readers of this study will chastise its authors to paint a too glorious picture of higher education in the US — and too dismal a picture of higher education in Europe or Switzerland. Keep in mind, however, the motive to engage in the present study: not to prove the superiority of one culture, of one nation, over others, but to understand the functioning of our institutions of higher education and to find ways to improve their effectiveness. We are not engaged in a discussion on the relative merits of hamburgers, Mickey Mouse, or Hollywood; we do not assess environmental or foreign policies, nor do we search for cues for the terrible attacks which occurred September 11, 2001. What we do want is to compare two leading institutions of higher education — in order to learn.

[2]It should be noted here that since the 1960s a new science evolved — under the names of bibliometrics, scientometrics, or information sciences — which focuses on measuring scientific output (see in this regard e.g.: `http://garfield.library.upenn.edu/`. This science forms a base for investigations such as those of CEST and provides vital information for sociological or institutional research studies.

Lastly, this study does not purport to present a final word. Quite to the contrary: the issues under discussion are far too complex for simple or definite solutions. What is required is an ongoing discourse, carried forward by a broad spectrum of concerned people: social scientists and administrators, educators and politicians, students. This discourse should enable periodic reforms and fuel a culture of responsible change. However, a personal bent will likely be characteristic of all these contributions. Take the following recollection, told by Nobelist MAX PERUTZ in his foreword to a study by JEAN MEDAWAR and DAVID PYKE on *émigré* scholars [152] (pp. xi-xii) :

> "Some years ago I ran into one of my Viennese friends of the 1930s. He asked me:
>
> 'What do you think of Fifi?'
> 'Who's Fifi?'
> 'Don't you remember, the girl with the *Dachshund*?'
> 'What about her?'
> 'Haven't you seen *Born Free*?'
> 'I have read it.'
> 'She emigrated to Kenya [...] and married the game warden Adamson'.
>
> Had Fifi remained in Vienna, she would have continued to keep dachshunds: it was her emigration that enabled her to keep a lioness instead. That story is symbolic of the greater opportunities many of us found in our new homes.
>
> Jean Medawar and David Pike tell the stories of the selected group of Jewish scientist and physicians from Germany and Austria whom the Nazis dismissed from their academic posts and who settled in Britain and the United States [...] According to the authors, their emigration was Hitler's loss and Britains and America's gain.
>
> As one of the scientists included in the book, I must protest. Like Fifi's, the gain was mine. Had I stayed in my native Austria, even if there had been no Hitler, I would never have solved the problem of protein structure, or founded the Laboratory of Molecular Biology which became the envy of the scientific world. I would have lacked the means, I would not have found the outstanding teachers and colleagues, or learned scientific rigour; I would have lacked the stimulus, the role models, the tradition of attacking important problems, however difficult, that Cambridge provided. It was Cambridge that made me, and for that I am forever grateful."

Raison d'étre and Structure of the Report PERUTZ's anecdotal evidence is just one of many reasons for the present study to juxtapose peer institutions — and to juxtapose MIT and ETHZ. This juxtaposition will not be symmetrical, however: MIT shall be used as a benchmark against which to assess the performance of ETHZ (and not vice versa). Apart from this case study we shall also try to present a synoptic sketch of basic questions and their ramifications. In general, we shall concentrate on structural matters and shall, with few exceptions, not be concerned with questions of content nor with specific pedagogic or didactic issues. In pursuing our focus on effectiveness and productivity, we shall make use of BOURDIEU's notion of morphology [20][3]. We are conscious of the fact that the object of our investigation is complex indeed, that the present study is of limited scope, and

[3] PIERRE BOURDIEU does not appear to define the notion of morphology explicitly. He uses the term to refer to student-faculty, staff-faculty and student-staff ratios and talks of the "morphological transformation of the faculties" (Appendix 2.1, pp. 243–250) and the "morphological transformation of the disciplines" (Appendix 2.2, pp. 251–255) over time.

that many more studies are needed to develop a deeper understanding of the issues under investigation.

The present Report is written in a rather condensed form — the result of our attempt to approach the theme more-or-less comprehensively and the short time frame available to develop the basic theses and present corresponding evidence. The aims of the Report are in line with the aims of CEST in general, namely to contribute to — and to enlarge the base for — a discussion of all those who are professionally involved or simply interested in research and higher education, in particular: policy makers, institutional administrators of universities and funding agencies; faculty, staff and student representatives; and researchers of higher education systems.

The Report is written in English, partly because this is the common language of its authors, but partly also because of our hope that an English report will attract a larger international audience than a report written in German. The Report has eight chapters plus various appendices[4]. Readers without the patience to go over the chapters and to reflect on the data presented are invited to read the Executive Summary and Conclusions (Chapter 1). The chapters themselves elaborate the subject matter pretty much from two perspectives: in accordance with the process model of the university, and from the perspective of an inter-cultural juxtaposition and comparison. After the introduction (Chapter 2), we start with a general presentation of the two institutions and a short description of their mission and their organizational setup (Chapter 3). In accordance with the process — or input-output — model of the university, the next three chapters will focus on the basic elements of such a model, including attempts to operationalize such elements and discussions of corresponding indicators: 'processes' — i.e. operations and functions — transforming input into output (Chapter 4), the 'input' or 'resource base' (Chapter 5), and the 'output' or 'product' of the institutions (Chapter 6). A preliminary examination of productivity issues will round out the presentation along the lines of the process model (Chapter 7). Lastly, we shall broaden our view to see the two institutions within their respective environment and history of higher education (Chapter 8). The perspective of an inter-cultural juxtaposition and comparison will be taken in all the chapters.

We want to compare two leading institutions of higher education — in order to learn.

In line with our general approach to present a more-or-less comprehensive sketch, we have tried to assemble references in order to illustrate our statements or guide the path to further investigations. As far as data are concerned, we have tried to present this Report as self contained as possible. For these reasons, we have excerpted data from other sources which we thought were vital for our argument; this information can be found in our Appendices. Data which had to be processed further or collated from various sources are included in the main body of the Report.

Acknowledgements The *Centre d'études de la science et de la technologie* (CEST) is instrumental for a new line of inter-institutional, comparative

[4]Two chapters were added subsequently; see our *Post Scriptum* below.

studies which we judge to be of great importance [33, 35, 34]. We want to thank CEST for the opportunity to contribute to this line of studies. Sections of this Report were read by the staff of CEST as well as by academics and professionals who, for the most part, are familiar with the climate of both MIT and ETHZ: Hanspeter Eichenberger (IBM Research Laboratory [Rüschlikon] and General Electric [Schenectady, NY], emeritus), Fritz Fahrni (ETHZ and University of St. Gallen), Kurt Hässig (University of Zürich, emeritus)[5], Joe Kaelin (Electrowatt-Ekono), and Hans-Jakob Lüthi (ETHZ). While we are grateful for the valuable suggestions and corrections of all involved, we take responsibility for any remaining errors or oversimplifications. Final thanks go to Jennifer Lüscher for her excellent editorial work.

Post Scriptum A discussion version of the Report, containing the chapters 1 through 8 (Part I: "A Basis for Discussion"), plus the appendices (Part III) and the Foreword, was distributed by CEST to representatives of higher education and institutional research in search of "feed-back on the issues presented". Responses and commentaries received are contained in Chapter 9, but some commentators opted to have their comments not published; in addition, a workshop was arranged by CEST and ETHZ (September 13, 2002) to discuss various aspects of the Report (see Part II: "Commentaries and Rejoinder"). The workshop was attended by the following persons: François Da Pozzo (CEST), Hanspeter Eichenberger (IBM Research Laboratory [Rüschlikon] and General Electric [Schenectady, NY], emeritus), Susan H. Frost (Vice President for Strategic Development, Emory University), Willi Gujer (ETHZ), Marcel Herbst (4mation), Urs Hugentobler (ETHZ), Hans-Jakob Lüthi (ETHZ), Georges S. Moschytz (ETHZ, emeritus, and Bar Ilan University, Israel), Werner Oechslin (ETHZ), Anne Roulin Perriard (CEST), Sotiris E. Pratsinis (ETHZ), Terrence R. Russell (Association for Institutional Research and Florida State University), Lydia Snover (MIT), Daniel Spreng (ETHZ), Ulrich W. Suter (Vice President for Research, ETHZ), Markus von Ins (CEST), Stark Wendelin (Ph.D-Student, ETHZ). Based on the responses received — in writing as well as during discussions — the authors of the Report formulated a rejoinder, contained in Chapter 10.

[5] Kurt Hässig, a wonderful colleague and friend, died September 6, 2002.

Part I

A Basis for Discussion

Chapter 1

Executive Summary and Conclusions

Every effort to transform the system which is not accompanied by an attempt to transform attitudes towards the system (and conversely) is doomed to failure.

Pierre Bourdieu, Jean-C. Passeron, Monique de Saint Martin [21]

The following summary and conclusions are divided into observations regarding (i) higher education systems in general, (ii) observations pertaining to the comparison of MIT and ETHZ in particular, and (iii) conclusions which are presented for discussion. Neither observations nor conclusions stem from an encyclopedic study. Observations and conclusions are frequently generalizations of the authors' views and past experiences, and they are consistent — we think — with the content of this Report; but we cannot claim that each generalization we make can be traced to particular sections or paragraphs.

The summary and the conclusions ought to be readable as a self-contained chapter — without having to rely on others, and despite some technical terms or concepts which are clarified or defined elsewhere. For these reasons, we want to sketch our assessment of the state of affairs of what we call European universities, without having studied in sufficient detail the whole array of European university systems. The observations themselves are to be seen as comparative: the European culture of higher education versus a US culture; the picture of one of the leading European research universities, the Swiss Federal Institute of Technology (ETHZ), versus the picture of a corresponding US institution, the Massachusetts Institute of Technology (MIT).

Lastly, these observations are not even-handed, not symmetrical; it was not our desire to be purely descriptive — if that were possible. It is not our objective to improve US higher education — or MIT for that matter, despite potentials for improvement, of course. However, it is our desire to express our concern for the state of affairs of European higher education, to help to improve European and Swiss universities and to encourage others to study the matter further.

1.1 General Observations

Research Performance Differentials There exists mounting evidence that research output differentials between US and European research universities are substantial, given comparable resource bases. The leading US research institutions seem to have a higher research productivity than comparable continental European institutions. In the past, differences were not really observed as being that significant because comparative analyses focused more on comparing nations rather than on institutions. New inter-institutional, international analyses point now to the fact that such differentials are much larger than previously thought. The differentials can be shown to exist if one compares leading research universities — such as MIT and ETHZ.

Research and Economic Development Research output, as measured by common output indicators, is widely thought to be positively associated with indicators of regional prosperity and economic development: technology transfer, the formation of start-up companies and the development of knowledge-based industries, the provision of associated employment opportunities and the formation and supply of corresponding human capital, et cetera. The link between research output on the one hand and economic prosperity on the other is tenuous, however, and requires not only the support of research universities but of the entire spectrum of education, from preparatory (primary and secondary) education to practice-oriented traineeships and to various forms of higher and continuing education.

Research Output and Education Research output might also be seen as an indicator of educational quality. Not of all education, to be sure, but of education at the leading research institutions, whether or not this education is pursued in the preparation of research. While there is a discussion about an inordinate concentration on research in research universities and a corresponding neglect of the educational mission, the relation between research output and educational quality is close in most institutions. Research output tends to be inversely correlated with drop-out rates and study periods of first degree — i.e. undergraduate or diploma level — education. In particular, research output can be viewed as an indicator of the quality of a research-oriented graduate education.

Performance and Institutional Morphology Research output and research performance indicators are linked to various aspects which characterize an institution: the funding base of the institution or its reputation, the admission processes by which an institution selects undergraduate and graduate students, the processes by which faculty and staff are recruited and the conditions under which faculty and staff are retained, et cetera. One aspect appears to stand out, however, as a factor contributing to — or stinting — research performance: morphological characteristics of an institution as captured by indicators such as student-faculty and the associated staff-faculty ratios. We can link institutional performance to these two indicators: leading, high performing research universities tend to have comparatively low student-faculty and low staff-faculty ratios.

Student-Faculty Ratios A research university with a given resource base and a given population of enrolled students has a larger faculty when the student-faculty ratio is low: each faculty member has fewer students to teach, to advise, to animate; and teaching loads and administrative duties are distributed over more shoulders. Because the resource base is assumed to be fixed, staff-faculty ratios are lower as well when student-faculty ratios are low: faculty work in smaller teams, together with doctoral and post-doctoral students; research administration is limited in scope; hierarchies are flatter; and faculty have colleagues alongside with whom to share ideas and problems within their field of specialty. If we assess low student-faculty ratios from the perspective of students, we observe that students have likely wider curricular choices; they attend smaller classes and have an earlier, more intimate contact with members of the faculty; active learning modes can be practiced more easily; students are likely pursuing their studies within a shorter period; graduate or post-doctoral studies can be attempted earlier, and a career path initiated sooner. Finally, all these factors seem to play together to increase research output and performance.

Cultural Differences in Higher Education Performance differentials and corresponding institutional morphologies seem to be due to cultural differences which separate not individual institutions as such but national higher education systems: the cultural heritage of higher education plays a dominant role when development paths are to be selected, when institutional change is to be managed. Higher education systems appear to be much more resistant to change than other service industries — or than science itself. This is particularly true in the case of European universities which cherish a Humboldtian tradition. While higher education might resist change, the environment, the societies and the context within which higher education operates are changing. The result is likely a mismatch between higher education institutions and their surroundings, a maladjusted course in pursuit of a time in flux.

Diversified Higher Education Systems Cultural differences are responsible for differing concepts and implementations of diversified higher education systems as well. With the onset of mass higher education in the decades after World War II, governments had to continually reevaluate their funding principles. And higher education systems, in turn, had to reorient themselves to cater to a larger and more diverse student population; they had to broaden their resource base, and they had to focus their mission in order to develop succinct institutional profiles. In the US, institutions and systems seem to have managed much better in adapting to mass higher education: institutions successfully diversified without blocking the inter-institutional flow of students, faculty and staff. In Europe, with its often latent opposition to mass higher education, the pretence of uniform quality levels of universities and within the various higher education systems, hampers a successful diversification of higher education.

Institutional Reluctance to Change While European institutions are gradually released from their bureaucratic shackles which have tied them to a governmental steering (or even micro-management) too far removed from the institutions themselves, they are not yet in a position to make use of their newly found freedom. While the gradually implemented institutional control of budgets (*Globalbudgets*) constitute an enormous improvement over times past, European institutions are still deficient — i.e. very conservative — in instituting organizational structures which ease trans-disciplinary work and the creation of new disciplinary programs; they are reluctant in implementing the necessary measures and co-requisites in support of modern budgetary — i.e. resource allocation — practices and the intra-institutional (even intra-departmental) transfer of resources; and in general they have internalized bureaucratic modes of the past and shy away from more 'user-friendly', 'customer' oriented practices.

New Government Control Conversely, governmental authorities are reluctant to transfer control to institutions or institutional systems. In exchange for the right to control budgets on the part of universities, European authorities increasingly rely on so called 'performance contracts' (*Leistungsaufträge, Leistungs-* bzw. *Zielvereinbarungen*), as if a contract alone — a consensual arrangement between government and institutions regarding the institutional mission, the available resources and the reporting arrangement — would not suffice. Performance contracts are criticized by knowledgeable scholars as the wrong tools of governance, as ineffective and perhaps even misleading measures, but they are clear signs of a still present lack of trust on wide parts of the public vis-à-vis higher education institutions.

Virtual Campus New technologies are thought to offer possibilities to adapt to — and to support — mass higher education, without requisite significant reforms of higher education systems. But this is unlikely so. New technologies cannot be used to save systems which have seen their times. The converse seems to make much more sense: only if we reform higher education shall we be able to make proper use of the emerging new technologies. While higher education is inherently labor-intensive, and while industrial productivity increases are often due to a substitution of capital-intensive for labor-intensive processes, the new technologies will not provide a substitute for a labor-intensive research university. We once thought that communication was a substitute for transportation and traffic, but it is more of a co-requisite. New technologies will support education and research, but they are no substitution for faculty and staff.

Trust and Credibility Finally, trust among the various agents of higher education has to be developed — or recreated if it was once there — and the institutions themselves will have to play a major part in that: they will have to give up their feudal vestiges and become truly service-oriented; they will have to invite and foster sensible change within their own institutions without being coerced, pressured or forced from the outside; they will have to become more open, more transparent, more accountable; they ought to pay tribute to talent and excellence, irrespective of its location; and they must function as institutions which take seriously the noble task of education: to help, to foster and to develop, not to hamper, to thwart or to exclude.

1.2 Particular Observations

Relative Position Based on doctoral degrees conferred, both MIT and ETHZ are leading research universities:

- both institutions confer roughly the same number of doctoral degrees;
- in engineering and in the physical sciences, MIT takes on rank 1 and 2, respectively, within the US — and in engineering and the physical sciences combined, rank one;
- in engineering, ETHZ would fall roughly into the top five ranks of US research universities; in engineering and the physical sciences (combined) ETHZ would rank number two (after MIT); and in the physical sciences and the life sciences (combined), ETHZ would have to be placed in rank one.

Performance The differences between higher education systems we have alluded to in general terms can be shown to exist if we look at the two institutions which form a case of the present study. MIT and ETHZ have a similarly sized resource — or input — base, at least as we look at the academic core of the two institutions (and not at various operations which are included in the overhead). But MIT appears to use these resources much more effectively:

- of 25 disciplinary fields assessed, MIT has higher counts of publication than ETHZ in 19 fields;
- in the fields where MIT has higher publication counts than ETHZ, MIT normally dominates ETHZ by factors of 2 to 10;
- at given levels of publication output, MIT sustains a significantly broader spectrum of disciplinary fields;
- and if we look at citations or impact, MIT's position vis-à-vis ETHZ is even stronger than in the case of publications.

A similar picture can be obtained if we are not comparing bibliometric indicators but Nobel prizes.

Morphology If we compare the morphology of the two institutions, we can observe significant differences. There are various differences in the organizational setup which can be linked to an institution's power to adapt to and manage change. And there are differences in the morphology which we tie — hypothetically for the time being — to the differences in performance:

- student-faculty ratios at the two institutions differ significantly: MIT has a student-faculty ratio of 11:1, ETHZ has a corresponding ratio of 34:1;
- if we look at doctoral students alone, MIT has a student-faculty ratio of 3:1, while ETHZ has one of roughly 7:1;
- because the resource bases of the two institutions are comparable, staff-faculty ratios show a similar pattern as student-faculty ratios: MIT has a staff-faculty ratio of 6:1, while ETHZ has a corresponding ratio of 15:1.

Organizational Setup MIT and ETHZ pursued different routes of development. While MIT and ETHZ have a similar mission, there are clear differences in their disciplinary orientation; furthermore, MIT formed schools subdivided by departments, while ETHZ formed divisions — which were later transformed into departments:

- MIT integrated the non-technical disciplines (humanities and social sciences) alongside their technical disciplines (engineering and natural sciences), while ETHZ relies on the non-technical fields as a source for liberal — or general — education;
- MIT has 5 schools and 20 departments, while ETHZ has no schools and 17 departments;
- MIT developed hierarchies above the level of the faculty, delegated decision-making powers to corresponding levels, and minimized hierarchies below the level of the faculty, while ETHZ has kept hierarchies above the faculty restricted and retained more extensive hierarchies below that level;
- ETHZ appears to be more fragmented than MIT: MIT has a total of 49 sub-units, all of which have an interdisciplinary orientation (divisions, programs, centers, laboratories, institutes, and groups), while ETHZ has 83 disciplinary units (institutes, laboratories, centers) and 8 interdisciplinary units (institutes, laboratories, centers).

Funding Bases MIT is a private institution with a broad funding base (e.g. endowment, licensing income, tuition and fees, federally and state sponsored research, industry collaborations) and ETHZ is a federal institution with a narrower funding base (e.g. federal base funding, public sponsored research, industry collaborations):

- With regard to financing teaching and research, MIT earmarks institutional funds primarily for teaching and uses funds derived from sponsored research and industry collaboration to finance research activities, while ETHZ finances a fair portion of research activities out of its own base funding;

- this difference in research funding appears to affect disciplinary and interdisciplinary activities at the two institutions: the — somehow controversial — hypothesis is that an external and competitive funding of research, in particular through public funding agencies, aids in the promotion of non-traditional research, provided funds are made available on a continuous basis and are distributed to some extent according to prospective merit (and not exclusively on the basis of evaluations of research proposals).

Change Management The thesis appears plausible that the existing performance differentials are (at least partially) attributable to differences in the morphology and the structural setup of the two institutions. Furthermore, morphology and structural setup might serve as key components with regard to the potential of the institutions to assume proactive roles and to adapt to required changes:

- If we look into the foreseeable future, MIT's position and context seem to be favorable in comparison to those of ETHZ's;
- although ETHZ has just recently revised its organization, this new organizational structure appears to have been designed with a view of getting rid of structural deficiencies, rather than with a view to form a structure which is more adaptable to the necessary changes of the future, and prospective avenues of change and development are unclear.

1.3 Conclusions

Structure and Morphology A debate should center (more forcefully than in the past) on the internal organization of Swiss research universities. Two linked issues will present themselves: (i) the structural setup above the faculty, the associated governance modes and the delegation of decision-making powers, and (ii) the morphology which presents itself at the level of the faculty and below:

- governance and management of modern research universities require professionals with a corresponding empowerment: activities cannot rely any longer on a — increasingly obsolete — militia-system;
- where disciplines are decently funded, the debate should concentrate on a possible thinning-out of academic staff, the so-called *Mittelbau*, so that the staff category would primarily be composed of doctorates and post-doctorates — in order to free resources for more faculty positions;
- structural and morphological changes at ETHZ — as well as changes in governance — will have to be accompanied by various institutional changes which serve as co-requisites (e.g. regarding

admission policies, credit systems, budgeting modes, implementation of new courses and programs, tenure-track systems and employment policies).

Funding Issues ETHZ, like other European research oriented institutions, ought to attempt to broaden their resource base (endowment, licensing income, industry collaborations), while still offering low student fees:

- in the context of expanded public funding schemes (currently under discussion in Switzerland), funding modes will have to be reviewed and more liberal, visionary funding practices will have to be tried;
- recent moves to delegate financial autonomy to institutions (*Globalbudget*) appear correct: they should finally lead to a much greater flexibility by which resources are distributed within institutions;
- funding agencies might have to play a more active and enlightened role, because research funds coming from the outside of the institution can be much more easily redistributed than funds allocated internally top-down;
- eventually, funding cannot be separated from admission policies: nationally there presents itself the issue which level to fund: the university sector vs. the non-university sector (*Fachhochschulen*); institutionally there presents itself the question which disciplines or programs to fund;
- admission in turn cannot be separated from academic programs: where there are too many students for given resources, funds will have to be generated to provide for better study and research conditions; alternatively, competing programs (within the same or at other institutions) will have to be started and financed to offer other educational opportunities.

Institutional Reforms Institutions must develop their self-critical and institutional learning capacities if they want to continually improve quality and survive as autonomous entities entrusted with a mission to serve society:

- the processes of reform ought to address the vestiges of out-of-date — feudal like — stratification systems (and their ramifications) which actually hinder performance.

Bologna Process The current European initiatives under the umbrella of what is termed the Bologna Process may evoke ambivalent responses. The Bologna Process offers opportunities for major — and constructive — changes with long lasting implications. On the other hand, the Bologna Process may prove to be ineffective or even harmful to higher education:

- the general scheme of three-layered educational programs (i.e. bachelor, master and doctoral degrees) offers great opportunities if properly envisaged and implemented: undergraduate education can redefine its mission; students can leave universities earlier, if only temporarily; and graduate schools can be built and graduate programs designed which admit students with a greater diversity of disciplinary — and institutional — backgrounds;
- transfer activities and the mobility of students should be coupled to properly implemented admission policies which are under the control of the institutions or institutional systems (and not the respective governments);
- the Bologna declaration should be implemented in a form which conforms with the diversification of higher education, a process deemed necessary if the quality of European higher education institutions is to be fostered.

Chapter 2

Introduction

Changing a university is like moving a graveyard — it is extremely difficult and you don't get much internal support.

Per Nyborg [169]

Comparative studies of institutions, departments or programs are conducted in the context of specific measures or general scholarly pursuits. Evaluation is one of the specific measures, applied in the academic context: it frequently follows the pattern of self-assessment and peer review [232, 115, 240]. It may serve different aims: to improve, strengthen or refocus existing units or programs, or to assess merits on which to base funding decisions. Evaluative measures have to be tailored to the task; they cannot serve the aim to coach and help if retrenchment lures around the corner. Conversely, if merit assessment as a base for funding decisions is the aim, peer review is unlikely to be conducted in a collegial atmosphere. Other specific measures, applied frequently in administrative contexts, include various forms of quality improvement techniques [111] or reengineering [93]. Apart from specific measures there are studies of a more general nature, even if they parallel approaches used in specific measures or focus on individual institutions [42]. The present study belongs to the latter category of endeavor.

Efficiency Concerns, Evaluation and Performance Contracting In recent decades one could observe a growing focus on questions of efficiency. With the advent of mass higher education [220] and the concomitant limitation of resources [3], institutions of higher education had to shed the image of the locus of an elusive elite, of an 'ivory tower'; they became increasingly subject to public scrutiny and accountability vis-à-vis governing boards, funding agencies, and society. Public institutions felt this new breeze in particular. The focus on efficiency brought about an extended interest in evaluation, specifically in continental Europe where auditing, self-assessment, peer review and accreditation measures where less developed than in the US. This underdevelopment of a culture of evaluation in the European context was due to a different form of governance of the university: one run under strict governmental regulations, less autonomous — and less diverse — than its US sister institutions, the European university of the past did not feel compelled to develop these measures.

The general lack of familiarity with evaluative measures, the corresponding reluctance on the part of the European universities to use these instruments for their own benefit and for the benefit of funding agencies, and new forms of public management led to increased pressures by the respective authorities to push for a focus on efficiency. In the context of mounting commitments in fields such as health insurance, transportation, education, environmental protection, et cetera, the public was increasingly doubtful whether their tax income was properly invested. As a consequence, new measures and practices were instituted, designed to increase transparency, accountability on the part of higher education institutions, and funding in function of 'established needs'. Leading this movement in Europe was the Thatcher Government in the UK [110, 32, 58] and corresponding practices of performance-based budgeting spread even to countries like The Netherlands or Scandinavia [98, 10, 16] where evaluation measures were under development as early as the 1980s.

Government-induced measures of performance contracting play a far greater role in Europe than in the US.

Accompanying the new focus of public management in Europe and the US was a search for new measures of goals achievement. While the institutions themselves had a natural proclivity to strengthen the proven means of evaluation, quality management and governance, governments and funding bodies opted increasingly for a top-down approach of performance-contracting[1]. Because European institutions were generally still less autonomous than their US counterparts — and also less inclined to creatively use their given autonomy for the benefit of the institution —, measures of self-governance are underdeveloped still and — hence — government-induced measures of performance-contracting play a far greater role in Europe than in the US [195, 194].

Input-Output Modeling of Universities Performance contracts are normally tied, in one form or another, to an input-output model of the university [8, 9]. In analogy to a industrial plant, higher education institutions are seen as processing units which transform input into output. In the course of this transformation value is added: generations become educated, science expands, economies get strengthened. Depending on the viewpoint, the entering student classes or the resources available can be seen as inputs; graduates or research findings, on the other hand, may be viewed as output; and the institutions with their specific characteristics serve as processing units, as transformers, of input into output.

While this model serves well in the course of scholarship or self-reflective investigations on the part of universities, it must be used with some restraint by funding agencies. Too numerous, still, are the open questions

[1] In the German speaking countries such contracts are known under the terms of *Leistungsaufträge, Leistungsvereinbarungen* and *Zielvereinbarungen* [94].

which prevent a water-tight allocation of resources [183, 158], particularly if applied in a mechanistic fashion. Universities are complex systems. Hence, benchmarkings require benevolent, knowledgeable scholars, administrators and politicians. Conclusions are often difficult to draw and wrong decisions are easily taken. If one focuses on cost indicators alone [78], we find that costs per student in European technical Universities differ easily by factors of 3 to 6[2]. What conclusions are we to draw from such observations?

- Are the more expensive institutions less efficient?
- Are graduates of the less expensive institutions not as well prepared?
- Are institutions more expensive than others because they focus more on research?

If efficiency is the concern of our time, we ought to have a clearer picture of what it might entail, of how efficiency is being defined in each particular case.

In general, efficiency refers to an output-input-measure[3]. But if we try to apply this concept mechanistically to the field of higher education and compute indices such as 'graduates per teacher' or 'costs per student', we might immediately see the danger. In the case cited above (with measured cost variations by factors of 3 to 6), what do we measure? Costs of educating a student? Not likely. The institutions studied are characterized by differing research intensities, but the major point is that cost accounting did not distinguish costs related to teaching and costs related to research. Indeed, this differentiation is difficult to accomplish because teaching and research feed on each other. But most importantly, neither of the institutions studied has a course credit system in place to trace — i.e. to account for — and manage resource allocation in that sector [147, 149].

Benchmarkings require benevolent, knowledgeable scholars, administrators and politicians.

The problems are not over, however, if we have the ability to distinguish (in our costing systems) between teaching and research. If we were to focus on teaching alone and wanted to raise efficiency, as defined, we could increase the number of graduates per teacher; in so doing, we would lower the cost of education per student. We could accomplish this by reducing the required time (or credits) to graduate, by increasing class size, by reducing the number of subjects taught, by keeping students enrolled over longer periods (and implicitly reducing the intensity of study), et cetera. But, in all likelihood, we would negatively affect educational or scholarly achievement as well. If standards or targets are imposed on universities, there is a great danger that these institutions will focus on meeting the targets set — to the detriment of aspects which are not contained in the funding formulae.

[2] According to FREIBURGHAUS [78], personnel input per student at ETHZ is roughly three times higher than at the RWTH Aachen and six times higher than at the TU Wien.

[3] Such as miles/gallon or horse-power/cubic-inch.

Efficiency, Effectiveness and Productivity The current concern with efficiency — or with general questions of quality [57, 56, 87] — is indicative of a general distrust of the public vis-à-vis institutions of higher education. It may also be seen as characteristic of an outsider's view: the concern to generate a service as cheaply, and as economically, as possible. Were it not for the difficulty to define the service, we could easily affirm a focus on efficiency. But the fact is that the service of a university is multi-dimensional and difficult to measure. Research on higher education may abound, at least in the international context, but many specific questions are under-researched, particularly in Europe. Hence, we clearly do not know what a university is 'worth' and at what input-output level it should be run; we have scant evidence concerning the economic impact of universities [188, 157, 89, 117]; and we are only beginning to relate output to input [164, 53].

The 'outsider's' position, i.e. the position taken frequently by people outside the institutions of higher education themselves, to provide a service — or a 'product' — as cheaply as possible, is in line with established economic thought, provided the service can be properly defined. This very basic assumption, however, is questionable as far as research universities are concerned, particularly in situations where the understanding of the higher education environment is lacking. There is no consensus on what should be achieved, and no operational consensus which might guide the running of institutions ought to be attempted: this would amount to managing institutions from the outside and would counter our notions of autonomous universities. But it is clear that citizens and politicians have a natural proclivity to assume such a viewpoint.

The study is formulated from an 'insider's' position — in order to help to improve institutions from within.

The 'insider's' position, i.e. the position taken by responsible governing boards, presidents, provosts or rectors, deans and administrators of higher education institutions, is to view the problem from the opposite direction: with given resources they attempt to be as effective, as productive as possible. A nation, a state should form a consensus on the level of support necessary — or feasible — to run a higher education system and should leave the institutions to manage their own affairs. A system of checks and balances ought to be in place to oversee this practice: institutions are accountable to governing boards, governing boards to governmental ministries and specifically designated positions and committees, and in the course of this accountability, reports are being issued on the mission pursued, on results achieved, on operative matters, on resources expended, and in general in order to enhance the transparency of the institutions.

Benchmarking The present study is formulated from an 'insider's' position — in order to help to improve institutions from within. Its aim is to gain a deeper understanding of the notion of productivity (or effectiveness) as it relates to institutions of higher education and, in particular, to research universities. A case study is used to focus on the theme: two institutions of corresponding size and similar disciplinary orientation — 'natural' peers — shall be compared: MIT and ETH Zürich (ETHZ).

MIT and ETHZ are both strong in engineering and the natural sciences, although MIT has — in contrast to ETHZ — also strong foci in other fields. MIT has roughly 10,200 students (see Table B.3), and ETHZ has a slightly larger enrollment of circa 11,700 (Table C.3); MIT employs in its academic sector about 6,500 individuals (see section 4.1.2), and ETHZ has a corresponding employee body of roughly 5,700 (head-counts). But there are also marked differences: MIT is a private (non-profit) institution and selects its student body actively; while ETHZ is a public institution with an open admission policy; MIT has a different morphology, to refer to a concept by PIERRE BOURDIEU [20], in that the number of professors (of all ranks) is close to three times higher than at ETHZ (910 vs. 340); MIT is more prolific than ETHZ as far as bibliometric indices are concerned; and MIT is run differently than ETHZ.

We have stated our aim to conduct a benchmarking study of a more general nature, and we have expressed our reservations vis-à-vis the purists of benchmarking. In general, benchmarking focuses on individual processes, operations or practices — and frequently in the administrative context [2]. In the field of higher education, such processes might cover purchasing operations, admission of students, library work, personnel administration, but also support of technology transfer or patenting, etc. In any of these fields benchmarking might compare internal operations against each other or compare internal operations with corresponding operations of peer institutions or competitors. The aim of this endeavor is to earmark operations which are subject to possible improvement and further study. Individual processes identified might then be looked at in greater detail on the basis of Total Quality Management (TQM) or Reengineering measures.

Benchmarking and TQM are seen as continuous, ongoing processes, while reengineering appears to have more of the quality of a periodic improvement instrument. At larger universities, dozens of teams are constantly involved to improve, to redesign or to reengineer individual processes or systems of processes. The general aims of these management techniques are a priori not clear: processes can be streamlined and made more efficient, requiring less resources; processes can be enhanced to increase their effectiveness, to reach a larger audience or client population; or they can be abandoned altogether or replaced by practices of similar orientations.

The benchmarking we focus on in the present study is of a much more general nature. Not individual processes or operations are in the foreground, but institutions in their entirety. We are not aiming to streamline administrative operations to increase efficiency, but strive to strengthen the academic core. We concentrate on issues of productivity, which form a research focus of CEST. Issues of productivity have not been well studied, however, despite their relevance in view of a growing international competition among higher education systems [168]: not within the bibliometric community, and not within the field of institutional research. Studies in related fields shall lead us in pursuing this focus [90, 91].

Chapter 3

Organizational Structure and Institutional Foci

Academic departments do not organize knowledge; they organize teachers and disorganize knowledge.

Russel L. Ackoff [1]

In the present chapter, we shall introduce the two institutions which we have chosen to juxtapose. We shall focus briefly on various points: the common origins and the development differentials of the two institutions, the respective role of liberal education and associated disciplinary fields, the structural development (particularly that of ETHZ), funding principles and their implications, and lastly the propensities for change. As we mentioned (in Chapter 2), the present study focuses on productivity issues and tries to tie these to a process model — and the morphology — of the university. Productivity, of course, is not only linked to morphology but to other factors as well: factors which we shall touch upon in this and other chapters, but which we are unable to treat in greater detail here.

3.1 Roots and Mission

Common Origins and Development Differentials As we have mentioned before, the two chosen institutions are natural peers and the aim to compare them suggests itself. Both institutions opened their doors in the same era of an emerging industrialization in the middle of the 19th century[1], and both institutions were conceived as technical institutes, not as universities, modeled after — or at least inspired by — various polytechnic schools which had opened up in the first half of the 19th century in Europe[2]. Both institutions

[1]ETHZ opened 1855 [223, 14], and MIT 1865/66 [140].

[2]A major school in this respect, and a precursor of various technical schools, was the *Ecole polytechnique*, founded 1794 in Paris. Subsequent foundations took place in Prague (1806), Vienna (1915), Karlsruhe (1825), Munich (1827), Dresden (1828), Stuttgart (1829) and Lausanne (1853) [223], pp. 18 and 23.

were located in newly emerging urban centers, to supply regional industry with the necessary human resources and to act as agents of economic development. The polytechnic school in Zürich was founded as a federal institute[3], and MIT was formed on the initiative of the Commonwealth of Massachusetts, providing a grant of land under the stipulation that this land be used "in promoting education, as well as directly developing the wealth of the state" [50]. Lastly, both institutes had similar disciplinary foci, but also interesting differences in their orientation. The polytechnic in Zürich (subsequent ETHZ) focused initially on six educational programs: architecture, civil engineering, mechanical engineering, chemistry, forestry, and mathematics and physics (as a combined field); in addition, courses in the fields of liberal education were offered. MIT initially also had six degree or diploma programs: mechanical engineering, civil and topographical engineering, practical chemistry, geology and mining, building and architecture, and general science and literature.

MIT and ETHZ are natural peers and the aim to compare them suggests itself.

In both institutions, the current structural setup cannot easily be traced back to the respective origin; but it is clear that the two institutions followed somehow different paths of development. As the institutions grew in size and as growing numbers of students and new fields and disciplines had to be integrated, MIT grouped disciplines into schools, whereas ETHZ added divisions to accommodate new degree programs (and subsequently formed departments). The two paths appear to correspond to two perceptions of organizational hierarchy which we shall focus on when we discuss the context of higher education (see Chapter 8). Organizational hierarchies are used to reduce complexities and to render organizations manageable. MIT, like other research universities in the US, did not shy away to create hierarchies above the faculty, while delegating decision-making powers to corresponding levels; in turn, hierarchies below the level of faculty were minimized to form and retain a collegial culture and to support close faculty-student relations. In contrast, ETHZ pursued a different avenue, in line with organizational principles which were characteristic for European universities. Conform with the notion that European universities need — or needed — "no elaborate system of administration" [11] (p. 15), ETHZ has kept levels of hierarchy above the faculty restricted, while hierarchies below this level were seen as necessary [24, 23].

Liberal Education, Social Sciences and Humanities Looking at the cradles of the two institutions, we can also see another major difference, a difference which pertains to the way liberal — or general — education was integrated into the two respective programs. At MIT, a regular degree course on "general science and literature" was formed initially and all students were

[3] After plans failed to create a federal university which would combine technical disciplines with medicine and law. In 1969, the Swiss Federal Government took over the cantonal *Ecole polytechnique de l'Université de Lausanne* (EPUL) as the second research university under federal auspices, under the new name of *Ecole polytechnique federale de Lausanne* (EPFL).

subjected to studies of languages[4], philosophy, history, political science, et cetera. In the early 20th century, discussions were intensified with Harvard University regarding a possible cooperation or alliance in these fields, discussions which appear to have ended around 1917. When, after World War II, a committee was assigned the task to evaluate the past 90 years of MIT's history, the proposal was made in 1949 to upgrade the initial commitment of MIT and to form a "School of Humanities and Social Sciences" [184] (p. 47). This upgrading was proposed even if it meant reallocating resources (p. 93):

> "The most important single thing the Institute [i.e. MIT] can do for general education is to increase the proportion of these people on the faculty. We have such people; we can have more."

This school was charged to go well beyond liberal education that was thought to be essential in the context of a technically-oriented university and to develop the corresponding fields at the graduate level as well. With this move, the humanities and social sciences at MIT were in a position to gradually mature, to gain the respect of the faculty in other disciplines, and — eventually — to become partners in various inter-disciplinary ventures and programs.

Humanities and the social sciences should not be restricted to their liberal arts function: they should assume an active role within a contemporary institute of technology.

Like MIT, ETHZ had an early commitment to liberal education, but in contrast to MIT, ETHZ had no formal degree program and was not accredited to confer degrees in this area (to this day). This 'deficiency', if we may call it as such, is clearly due to the founding principles on which the polytechnic in Zürich was based and the arrangement between cantons (in charge of universities) and the federal government in which it was implicitly stipulated that the federal polytechnic institute would not compete with the cantonal universities[5]. While the principle of liberal education was respected at ETHZ all through its history, the potential of the humanities and social sciences for an institute of technology was not even seen by Karl Schmid, a former rector of ETHZ and himself an eminent scholar of German language and literature [191]. At ETHZ, humanities and social sciences were concentrated in a specific division (finally the *Abteilung XII*) before giving way to two corresponding departments (which have merged subsequently). Courses in the *Abteilung XII* were attended out of interest and joy, even by faculty, and would not be graded. But because the humanities and social sciences at ETHZ had no degree programs of their own, they lacked graduate and Ph.D students[6], they were restricted in their own research activities, in their abil-

[4]French and German — but also of Spanish or Italian —, because many leading science and engineering books were written in those languages.

[5]This notion has long been out of date, perhaps even from the very beginning, because natural sciences (including mathematics) were covered at the polytechnic institute as well as at the universities. The original argument, perhaps, was that engineering demanded the presence of the natural sciences at the polytechnic. True enough. The same argument could now be used to force a stronger integration of humanities and social sciences into ETHZ.

[6]Faculty at ETHZ normally found ways to circumvent these restrictions somehow, through associations with faculty of other research universities.

ity to stimulate and affect engineering and the natural sciences, and in their opportunities to engage in interdisciplinary projects.

In one of the 'vision papers' of ETHZ, the planning commission proposed some years ago that the federal institute pay more attention to the humanities and the social sciences and to put them on an equal footing with engineering and the natural sciences [68] to form a 'triad' of sciences. The argument behind this proposal was that the humanities and the social sciences should not be restricted to their liberal education function: they should assume an active role within a contemporary institute of technology. While the natural sciences have a predominant descriptive function and while engineering and other professional programs[7] are preoccupied with the search for solutions, many — if not most — phenomena and problems modern sciences grapple with have strong anthropogenic, man-made components which cannot be understood unless the humanities and the social sciences make — and are allowed to make — their contribution.

There are clear differing visions deemed instrumental in fostering the interplay between established disciplines and the founding of new ones.

A further argument in favor of the social sciences and the humanities centers on the observation that in the industrialized nations the service — or tertiary — sectors have become the dominant sectors of the respective economies. When Fourastié, for instance, forecasted after World War II that the pyramidal structure of our economies — with the primary sector as the foundation and the tertiary sector on top — would be placed on their head, the forecast appeared speculative [75]. Today, not the primary and secondary sectors of our economies are the most labor-intensive, but the tertiary (service) sector: roughly two thirds of all employees work in this sector. This change of employment opportunities has not yet been properly reflected by the disciplinary orientation of ETHZ, although some recognition has been given[8]. While the vision paper of the planning commission was formally accepted by ETHZ's government board, it is difficult to implement considering the present budgeting and management practices. But the vision paper helped to integrate the corresponding courses better into the curricula of the various departmental programs and to fight off recent attempts to scratch the faculty of the former *Abteilung XII* altogether[9].

[7]Like medicine (i.e. programs regarding MD's), for instance.

[8]ETHZ's Vice-President Gerhard Schmitt addressed the Heads of Departments (January 11, 2000) to focus on this issue. Some initiatives are under way to strengthen the more quantitative — mathematically oriented — social sciences, such as the financial sciences, system design & management, et cetera.

[9]The argument of the political representatives involved, which was widely given space in the press, was that the humanities and the social sciences at ETHZ served the function of liberal education, a function which could be taken over more economically by adjunct faculty recruited from universities specializing in the corresponding fields, such as the University of Zürich.

3.2 Structure, Development and Interdisciplinarity

The integration of the humanities and social sciences into a complex of technically-oriented sciences is just one aspect of a general and long established tendency towards interdisciplinary — or trans-disciplinary — approaches to epistemology and problem-solving. Science, so the thinking goes, should be approached from whatever angle is appropriate and disciplines should be free to work together on common problems. While this notion is generally not disputed, there are clear differing visions deemed instrumental in fostering the interplay between established disciplines and the founding of new ones. This topic, of course, touches on philosophical and pedagogical issues which are outside the scope of this study. But we would like to focus on one aspect which appears central to the viability of institutions: the interplay between the organizational structure and the ability of the members of this institution, faculty and students, to pursue their studies and play productive roles.

Structural Development at ETHZ In order to exemplify the problems, we shall sketch the historical development at ETHZ. In the 1990s, ETHZ had 19 divisions[10] and a matrix organization was formed: divisions to focus on degree programs[11], and departments in charge of research. Because the matrix organization thus formed was not considered too successful[12], the matrix organization was eventually abandoned to give way to a new structure which was implemented in 1998[13].

Looking back in time as the divisional structure of ETHZ unfolded, we see that divisions were added as new degree programs were formed:

- Already in the 19th century, two professional divisions were added to the original six: 'agriculture', and 'rural engineering and surveying';
- at the beginning of the 20th century 'natural sciences' were added, and in 1935 'electrical engineering'[14];
- after World War II 'pharmacy' was separated from 'chemistry'; at that point, ETHZ had eleven divisions (with degree programs).
- In 1968 a group with a focus on computer sciences was formed after the field itself began to take shape in the 60s [72, 156]. In 1970 initiatives were started within the division of 'mathematics and physics' to form a separate division [244, 19]; the division was eventually formed

[10]Apart from the divisions mentioned, ETHZ had formed the following divisional units: 'material sciences' and 'management engineering', both carved out of the division of 'mechanical engineering'; 'military sciences' and 'physical education', programs which ETHZ had to offer as a federal institution — and which did not count as normal degree programs; plus 'liberal education'.

[11]Towards the end of this process, there were few divisions which administered two degree programs each.

[12]In most cases, divisions and departments were matched one-to-one and parallel administrative structures had to be formed.

[13]See "Verordnung über die Organisation der Eidgenössischen Technischen Hochschule Zürich, vom 14. Mai 1998.

[14]The degree program of electrical engineering existed since 1924.

in 1981, late — or too late — as some would suggest, against the early opposition of mathematicians and electrical engineers.

- A similarly slow development can be observed in the case of the division of 'environmental sciences', formed 1988 [124], after similar initiatives and programs elsewhere had already been in existence for decades. In this case the opposition to a separate focus on environmental sciences was voiced most strongly within the divisions of chemistry and biology (which had earlier separated itself from 'natural sciences') .

While certain initiatives to form new units or programs at ETHZ were successful, if only eventually, others were not. When, in the 1990s, the management of ETHZ expressed its aim to fuse the two divisions of 'civil engineering' and 'rural engineering and surveying' (the two divisions which corresponded to the newly formed Department of Civil Engineering & Geomatics), various faculty committees studied this merger over a period of two to three years, only to conclude that it was not advisable. The merger eventually became pointless when ETHZ abandoned its matrix structure.

Another example: Towards the end of the 1990s, ETHZ was approached with an initiative (from the outside) to form a program in 'landscape architecture', because such programs where not available in Switzerland at the university level: graduates were sought, and faculty-training was a further goal of the prospective program. At the time, the program in architecture was the largest at ETHZ (with over 1,500 students) and produced graduates which could not easily be absorbed by the labor market; some of the prospective architecture students, as well as others, may have opted to enroll in such a newly founded landscape architecture program. The program would have bridged activities in fields such as architecture, forestry, and environmental sciences. A committee studied the proposal and came to the conclusion, against some strong opposition within the committee itself, that landscape architecture lacks the scientific credentials worthy of a full diploma program at a university[15]. The committee found no majority in favor of any ways to form such a degree program at the time, and essentially postponed the decision and delegated it to a future generation of faculty[16].

Funding Principles We have mentioned that MIT and ETHZ pursued two different avenues of development. As both institutions grew, as greater numbers of students and faculty had to be integrated, and as new fields of investigation came to the foreground, the institutions organized themselves differently to meet these challenges. But it is not only the internal organization which separates MIT from ETHZ, it is also the way the two institutions are funded and the way budgeting takes place internally [237, 147, 149].

[15] "Harvard University was the first university to offer a four-year course leading to a degree in landscape architecture [...] That [course] began during the forty-year reign of [...] of Charles William Elliot, who held sway over the University from 1869 until 1909" [186].

[16] The new development is such that a network of five institutes — *Netzwerk Stadt und Landschaft (NSL)* — is being formed which is to study phenomena of urbanization and suburbanization. The NSL is to offer two graduate programs: in Urban Planning and Landscape Design, and in Facility Management. See `www.ethlife.ethz.ch` (June 7, 2002).

Table 3.1: MIT, ORGANIZATIONAL UNITS, based on: `web.mit.edu/communications/orgchart`.

		interdisciplinary:					
SCHOOLS (OR COLLEGE):	Departments	Divisions	Programs	Centers	Laboratories	Institutes	Groups
School of Architecture & Planning	2	—	1	1	1	—	—
School of Engineering	8	2	5	5	6	—	—
School of Humanities & Social Science	4	—	4	1	—	—	—
Sloan School of Management	—	—	4	6	1	1	1
School of Science	6	—	—	3	2	—	1
Health Sciences & Technology	—	2	—	2	—	—	—
TOTAL	20	4	14	18	10	1	2

While this theme opens up another line of investigation which is outside our proper scope of investigation, a few remarks shall be in order.

The difference between MIT and ETHZ is not so much the fact that MIT is a (so called) private university and ETHZ a public — and federal — institution[17]; the difference has a cultural dimension (see Chapter 8): US institutions — and the research universities — retained a (comparatively) strong commitment towards undergraduate education [22, 116, 187], despite voices of concern. In line with this basic commitment, institutional funds — of public or private universities — are primarily used for educational purposes, for teaching, while research is financed predominantly from outside sources. This division of funding, linked also to a culture of grantsmanship on the part of US institutions, is frequently criticized by European scholars as being too complicated or even ill-advised because basic (undirected) research — in contrast to applied fields — may suffer[18]. Indeed, this view was voiced in the earlier periods of a discussion on interdisciplinarity in the US as well. As LISA LATTUCA reports [130] (p. 43):

Institutional funds of the US research university are primarily used for educational purposes, for teaching, while research is financed predominantly from outside sources.

> "Typically the departmental structure of the university and institutional reward systems are considered major barriers to interdisciplinarity since they presumably are based on disciplinary models of research and teaching."

However, she continues:

[17] Today, there exist six such institutions, two research universities, ETHZ and her sister institution in Lausanne (EPFL), and four research institutes within a corresponding domain. See `www.ethrat.ch`.

[18] In Switzerland, this criticism has taken on an added dimension vis-à-vis the European administered research funding.

> "Among its advantages are the availability of 'hard money' [i.e. internal funds] and the resulting flexibility and opportunity to initiate projects that might not be funded by outside sources; the opportunity to create interdisciplinary project teams on an ad hoc basis; the availability of a pool of disciplinary experts to work on interdisciplinary research projects; and an environment in which academic experts have the freedom to choose their research projects and collaborators without administrative or other approval."

If we compare this US position with the European position, we have to keep in mind that the cited US position is a comment on the early interdisciplinarity discussion (i.e. around 1975) and reflective of the prevailing morphology of the US university.

Research funds coming from the outside of the institution can be much more easily redistributed than funds allocated internally top down.

Our thesis is not in contrast to the position LISA LATTUCA reports, but it modifies and expands on her thesis. We state that flows of funds, together with the morphology of the institutions (see, in particular, Chapters 4 and 8), are in large measures responsible for the structural and organizational setup of the institutions — and, hence, to some extent also responsible for the way interdisciplinary educational and research approaches become manifest. According to this hypothesis, research funds coming from the outside of the institution can be much more easily redistributed than funds allocated internally top-down. Because the faculty of MIT, like in other leading research universities in the US, receives a fair share of their resources from the outside[19], resources can be invested in various research and teaching programs, depending on the aims of the faculty involved and in line, of course, with the general mission of the institution.

Implications If we pursue this thesis and look at the organizational setup of MIT, we see that the institute today is organized into five schools and one college; these units in turn are subdivided into 20 departments and into 49 interdisciplinary — cross-departmental — centers, labs, or programs (see Tables 3.1, B.2 and B.3). While the departments are hosts of the major degree programs (Table B.4), degrees are also conferred in subdivisional fields (see Tables B.5 through B.9), because MIT's students have greater liberty to arrange their own learning foci[20]. Furthermore, special interdisciplinary programs, centers, divisions, laboratories and groups are being cross-financed in support of teaching and research.

[19]In the year 2000, MIT received federal research-and-development grants in the amount of $ 307 million, not including funds which were directly earmarked to fund university-associated federally financed research-and-development centers (see: "Top Institutions in Federal Research-and-Development Expenditures, 1999 and 2000", The Chronicle of Higher Education, March 1, 2002, p. A24). In addition, in the fiscal year 2000, MIT received a licensing income from patent activities in the amount of $ 30 million [17]. MIT claims research sponsorships in the year 2000 in the amount of $ 384 million; and that internal research funding amounts to only 1% of the total [141] (p. 21).

[20]This liberal approach, also in line with a more general liberal attitude of US institutions, centers on well established credit and advising systems.

Table 3.2: ETHZ, ORGANIZATIONAL UNITS, based on [69] and `www.ethz.-ch/research/departments_en.asp`.

						interdisciplinary:			
SCHOOLS (*Fachbereiche*):	Departments	Programs	Institutes	Laboratories	Centers	Programs	Institutes	Laboratories	Centers
Construction & Geomatics	2	5	12	1	—	—	1	—	—
Engineering Sciences	5	5	17	10	2	—	2	1	1
Natural Sciences & Mathematics	4	5	12	7	2	2	2	—	1
System-Oriented Sciences	5	7	15	1	—	—	—	—	
Other Sciences	1	2	4	—	—	—	—	—	—
TOTAL	17	25	60	19	4	2	5	1	2

ETHZ's research units are more fragmented — and localized — than those of MIT.

Pitting MIT's setup against that of ETHZ, we see that ETHZ currently has 17 Departments, but no schools (see Table 3.2). The departments of today cover five broad disciplinary sectors, so called *Fachbereiche*, which have no organizational significance (they are listed for statistical purposes only). ETHZ has strong foci in engineering and the sciences but, as we mentioned before, just a rudimentary orientation towards the arts and the social sciences. The 17 departments of ETHZ support now 25 disciplinary degree programs plus 2 inter-disciplinary programs[21]. The departments are also homes for 83 disciplinary institutes, laboratories or centers. Finally, there are 8 interdisciplinary institutes, laboratories or centers[22].

If we compare this statistic with that of MIT (i.e. of Table 3.1), we see that ETHZ has roughly twice as many subunits than MIT, and most of these have a disciplinary orientation. If we consider, furthermore, the fact that MIT has a much larger faculty (see Chapter 4), we come to the conclusion that ETHZ's research units are much more fragmented — and localized — than those of MIT:

- low staff-faculty ratios (Chapter 4) and predominant external research funding seem to work in favor of cross-disciplinary approaches; and
- high staff-faculty ratios and predominant internal research funding appear to correlate with disciplinary fragmentation.

It will have to be be a matter of further research to investigate the significance of this thesis (see Table 3.3 for a condensation of the observed differences).

[21] One in 'natural sciences' and the other in 'computational sciences'.

[22] Institutes: Regional Planning (ORL), Bio-Medical Engineering (jointly with the University of Zürich), Military Security Technology, Institute of Neuroinformatics (jointly with the University of Zürich), and Institute for Operations Research; laboratories: Biomechanics Laboratory, Risk Lab; centers: Neurosciences (jointly with the University of Zürich), Energy Policy and Economics.

Table 3.3: MIT AND ETHZ, ASPECTS OF STRUCTURAL DIFFERENCES.

ASPECT:	MIT	ETHZ
Developed Hierarchies	above faculty	below faculty
Staff-Faculty Ratios	small	large
Research Funds (primary sources)	external	internal
Organizational Units	focused	fragmented
Inter-Disciplinary Units (relative share)	large	small

Change Management The above sketches document to some extent the organizational changes that have taken place at MIT and ETHZ since their inception. Both institutions chose different development paths, partly because they had to confront other challenges and partly because they opted for separate response strategies. These two development approaches are due to the two higher education cultures of which the institutions are part of, and due to the individual conceptions of the various leaders, change agents and decision-makers which had shaped the two institutions, i.e. differences which will have yet to be investigated if we more fully want to understand the development of the respective research universities.

Both institutions chose different development paths, partly because they had to confront other challenges and partly because they opted for separate response strategies.

Apart from these differences, we can also note some important common grounds. Both institutions paid great attention to their physical infrastructure and to corresponding instrumentation so necessary at technical universities. MIT built a fine urban campus with outstanding examples of architectural design [205]. ETHZ was not as fortunate as MIT to be able to expand on one site, but the chosen two-campus solution proved farsighted and the elaborated technical standards and associated planning processes are exemplary[23]. Infrastructure is a necessary prerequisite for excellence, it mirrors to some extent organizational structures and it can be used as a vehicle to manage change [222].

[23] See: www.bau.ethz.ch/.

Chapter 4

MIT and ETHZ: Operations and Functions

Education is not to be viewed as something like filling a vessel with water but, rather, assisting a flower to grow in its own way.

Noam Chomsky [137]

We shall start with an exposition of the input-output model in that we focus on process-indicators which are judged to be indicative of quality of operations. Regarding the academic sector, this covers student-faculty ratios pertaining to the non-doctoral and doctoral levels of study, staff-faculty ratios, as well as indicators pertaining to graduation processes (completion rates, cross-over rates, and study duration). Regarding the non-academic sector and its relation to the academic sector, staff-staff ratios may serve as indicators.

4.1 Academic Sector

4.1.1 Student-Faculty Ratios

The numerical relation of student to faculty populations is frequently used as an indicator of educational or institutional quality [236]. The relation is normally referred to as the student-faculty ratio (and in some cases by the inverse, the faculty-student ratio — or the staffing ratio) [123]. In the German speaking world, the term *Betreuungsverhältnis* is used to refer to this concept. Student-faculty ratios refer to the average size of the student body (or class) by faculty member; they vary by:

- subject or discipline;
- the form of instruction, the environment of learning, or the level of education;
- the mission, heritage or style of the institution.

Table 4.1: STUDENT-FACULTY RATIOS of Selected Universities (Year 2000), based on various internet sources.

UNIVERSITY:	Student-Faculty Ratio
RWTH Aachen	83:1
Technische Universität Darmstadt	50:1
TU Delft	54:1
Universität Karlsruhe	48:1
Technische Universität Wien	67:1
Universität Zürich	63:1
University of California (Berkeley)	26:1
University of Michigan (Ann Arbor)	14:1
Princeton University	10:1
Georgia Institute of Technology	21:1
Harvard University	16:1
Stanford University	12:1

Instruction-intensive subject matters (such as music) may require very low student-faculty ratios; and the disciplines of the sciences, engineering and medicine allocate normally more faculty than those of the humanities and the social sciences, particularly in Europe. Lecture courses require less faculty per student than seminars, as do computer-guided self-study programs and — perhaps — distance-education programs [102]. Finally, there is a tendency to allocate more faculty to graduate as compared to undergraduate education, although this might also be reflective of the mission — and the heritage — of the institutions under consideration.

In the US, overall student-faculty ratios at leading public research universities tend to average around 20:1; and corresponding private research universities have ratios of roughly 15:1 or 10:1[1]. In Europe, with different foci in higher education, high overall ratios — of 40:1[2] or more — are common (see Table 4.1). In order to interpret these figures, we shall have to look at the components which make up these ratios, the number of students on the one hand and the number of faculty members on the other.

Issues of Measurement In Europe, student numbers refer — generally — to head counts (and not full-time-equivalents). If students pursue their studies part-time, their studies take longer than the norm — while they are counted as students. Because the actual duration of studies is often 20-40% longer than the norm, student number statistics (as a base for faculty workload assessment, for instance) are frequently inflated correspond-

[1] NEIL RUDENSTINE, the former president of Harvard, writes regarding student-faculty ratios (see also Table 4.1): "More can be accomplished with the resources we already possess. But at Harvard, our [student-faculty] ratio is less favorable than those of some other universities with which we compare ourselves. If we want to make progress — especially in our most heavily enrolled departments — we will have to add faculty on a selective basis" [187] (P. 11).

[2] In Switzerland, the overall student-faculty ratio at the university level today is around 36:1; see: `www.statistik.admin.ch/stat_ch/ber15/dber15.htm`. The corresponding figures in Germany are around 49:1; at the non-university level (*Fachhochschulen*) the student-faculty ratio is circa 31:1; see [27].

ingly[3]. Furthermore, individuals might inscribe themselves as students, not in order to pursue studies as such, but in order to benefit as holders of an insurance policy or recipients of subventions[4]. For these reasons, 'actual' student-faculty ratios might not be as high as computed and will have to be assessed with some care.

Low student-faculty ratios are seen as having positive impact on student-faculty relationships, on active learning support, on breath of programs and curricula, on interdisciplinary course offerings, on mentoring.

An analogous argument is sometimes made concerning the validity of faculty figures while computing student-faculty ratios[5]. The generally lower student-faculty ratios of US institutions (in comparison to those of Europe) might not only be due to the possibly inflated numbers of European students but due to an 'inflated' number of US faculty. US faculty of the professorial rank is 'inflated', so the argument goes, because many individuals at European institutions of lesser rank would be qualified to work at the professorial level at US institutions. Indeed, a range of individuals at Swiss or German institutions working as *Oberassistenten*, for instance, had in the course of their prior careers been employed at the assistant or even the associate professorial level at one of the US institutions. While we don't deny the academic qualification of many European individuals of the so called *Mittelbau*, we do not view the problem as a definitional one or one of classification. Academic staff other than of professorial rank is not counted here as faculty, because this staff is not autonomous[6]. We shall return to this point when we discuss matters of productivity and performance (see Chapter 7).

As we can see (in Table 4.1), US institutions tend to have significantly lower student-faculty ratios than European institutions. These figures are lower not because the data bases are differently defined, but because US institutions assign a different role to faculty — and a different significance to student-faculty ratios. As ALEXANDER W. ASTIN remarks [9] (p. 328): "The student-faculty ratio is one of the most discussed policy issues in higher education [...] Many institutions emphasize a low student-faculty ratio in their promotional materials, [...]" [7]. Low student-faculty ratios are seen as having positive impact on student-faculty relationships, on active learning support, on breadth of programs and curricula, on interdisciplinary course offerings, on mentoring. Some of these positive impacts come to mind when we invoke

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[3]Longer duration of studies, to be sure, do not necessarily imply a lesser intensity of study (e.g. in the form of part-time studies) and a diminished use of institutional resources. If these longer-than-norm studies are not those of part-time students, there might be questions concerning the effectiveness with which studies are pursued.

[4]A few years ago, the University of Zürich had around 30,000 students enrolled. When fees were raised (presumably to raise income), student numbers dropped immediately to roughly 25,000, reducing also the income the university received from inter-cantonal transfer payments for students originating in Cantons without a university. Today, the University of Zürich has about 21,500 students; see: `www.unizh.ch`. See also [176].

[5]For the purposes of the present study, faculty refers to personnel of the professorial level; see also Table B.1.

[6]As far as the definitions of academic autonomy of faculty members are concerned.

[7]In fact, if one screens the web for the respective terms, one accumulates thousands of hits.

the German translation of the student-faculty ratio, the *Betreuungsverhältnis*. But it is not only the aspect of teaching (in the narrow sense) which is of interest in this context, but also the concern with research, the interplay of faculty with doctoral and post-doctoral students, etc. Consequently, the morphology of the faculty and staff structures — or the staff-faculty-ratio (see Section 4.1.2) — of US institutions is distinct from those of European institutions.

MIT If we try to compute student-faculty ratios for MIT at the level of the individual school or program, and base these ratios on student and faculty counts, we have to keep two aspects in mind:

- MIT students do not enroll in a particular academic program until the 2nd year of their studies; hence, the required student numbers by school (or program) in the first year will have to be artificially constructed or estimated (see Table B.3);
- faculty are members of particular schools (or programs), but they teach not only in their home departments but in other schools (or programs) as well (see Table B.2).

For these reasons, student-faculty ratios, as computed (see Table 4.2), have to be viewed with some reservation. We see that student-faculty ratios (as computed by us) vary from a low ratio of 3:1 (in the School of Humanities & Social Science, a net exporter of faculty services) to a high ratio of 121:1 (in the Health Sciences & Technology program, a net importer if faculty services, particularly from the Schools of Engineering and Science). A more precise assessment of student-faculty ratios would require the use of a statistics on credit units taught (with a focus on undergraduate and graduate instruction)[8]. The average student-faculty ratio for MIT as a whole, however, is around 11:1, a figure which appears characteristic for the individual units or the institution as well[9]. The very low student-faculty ratio for the School of Humanities & Social Sciences, quite uncharacteristic for these academic fields, can be explained by the service function of that particular school in the technical institute.

A more detailed (and precise) picture of student-faculty ratios is given in Table 4.3. The Table shows that for every member of the faculty of MIT there are 8.3 non-doctoral students enrolled and 3.0 doctoral students (26.3% of MIT's students are enrolled at the doctoral level). Some schools have a greater share of doctoral students than others, a reflection also of their basic orientation (professional training versus academic/research focus)[10]:

[8] A statistic which is not at our disposal at present.

[9] With such a student-faculty ratio, MIT is among the leading research universities in the US, and possibly in the world, regarding its focus on a close student-faculty interplay; perhaps only surpassed by the California Institute of Technology which has a student-faculty ratio of roughly 7:1, and whose "[…] mission [it is] to train creative scientists and engineers […] by conducting instruction in an atmosphere of research, accomplished by the close contacts between a relatively small group of students (approximately 900 undergraduate and 1,100 graduate students) and the members of a relatively large faculty (approximately 285 professorial faculty, 65 research faculty, and 560 postdoctoral scholars)" (see `http://pr.caltech.edu/catalog/01_02/geninfo/geninfo.html#undergraduate`.)

[10] Yearly averages of 1999-2001.

Table 4.2: MIT, STUDENT-FACULTY RATIOS AND RELATIVE SIZE OF STUDENT BODY (in %): by School or Program (Yearly Averages 1999-2001), based on [139]; and Tables B.2 and B.3.

SCHOOLS (OR PROGRAM):	Student-Faculty Ratio	Relative Size of Student Body (%)
School of Architecture & Planning (incl. MAS)	11:1	7.6
School of Engineering	15:1	50.1
School of Humanities & Social Science	3:1	5.0
Sloan School of Management	13:1	11.3
School of Science	8:1	19.6
Health Sciences & Technology	121:1	6.3
MIT OVERALL	11:1	100.0

Table 4.3: MIT, STUDENTS PER PROFESSOR: by School or Program and by Level of Instruction (Yearly Averages 1999-2001), based on [139]; and Tables B.2 and B.3.

	Students per Professor (by Level):		
SCHOOLS (OR PROGRAM):	Non-Doctoral	Doctoral	Total
School of Architecture & Planning (incl. MAS)	8.4	2.8	11.2
School of Engineering	12.0	3.3	15.3
School of Humanities & Social Science	1.7	1.7	3.4
Sloan School of Management	12.0	0.9	12.9
School of Science	4.1	3.6	7.7
Health Sciences & Technology	95.9	25.5	121.4
MIT OVERALL	8.3	3.0	11.2

- School of Architecture & Planning (incl. MAS): 25.1%,
- School of Engineering: 21.3%,
- School of Humanities & Social Science: 50.4%,
- Sloan School of Management: 6.6%,
- School of Science: 46.5%,
- Health Sciences & Technology: 21.0%.

ETHZ At the Swiss Federal Institute — and in contrast to MIT — students enroll in their respective departmental program from the very beginning. As far as initial instruction in the basic sciences is concerned, ETHZ employs a similar policy as MIT in that courses are taught by faculty members of the respective departments, irrespective of the department where the courses are given. For instance, the departments of Chemistry, Mathematics and Physics at ETHZ are net exporters of faculty services[11].

[11] A comment has to be made concerning the reported structure of ETHZ (in five Schools or *Fachbereiche* — see e.g. Table 4.4). These are for statistical purposes only: ETHZ has 17 Departments, but no schools and no corresponding organizational structure (see Chapter 3); nonetheless, the yearly reports show departmental statistics structured by *Fachbereiche*.

Table 4.4: ETHZ, Student-Faculty Ratios and Relative Size of Student Body (in %): by *Fachbereich* (Yearly Averages 1998-2000), based on Tables C.1 and C.3.

Schools (Fachbereich):	Student-Faculty Ratio	Relative Size of Student Body (%)
Construction & Geomatics	38:1	18.4
Engineering Sciences	40:1	31.0
Natural Sciences & Mathematics	26:1	22.7
System-Oriented Sciences	35:1	21.2
Other Sciences	32:1	6.7
ETHZ Overall	34:1	100.0

On the bases of these remarks, we can refer to the student-faculty ratios of ETHZ (see Table 4.4): they vary between 26:1 (Natural Sciences & Mathematics, net exporters of faculty services) and 40:1 (Engineering Sciences, net importers of faculty services). The average student-faculty ratio for ETHZ as a whole is circa 34:1 — or roughly three times less favorable as that of MIT[12], but slightly better than the average in Switzerland, and clearly better than other leading universities in Europe (see Table 4.1).

Again, a more detailed (and precise) picture of student-faculty ratios is available in Table 4.5. The table indicates that, for every faculty member at ETHZ, there are 27.5 non-doctoral students enrolled and 6.7 doctoral students. If we compare these figures with those of MIT, we see that a faculty member at ETHZ is responsible for the guidance of more than twice as many dissertations as the colleague at MIT; furthermore, faculty at ETHZ are entrusted (on a per head basis) to instruct, coach, advise and animate more than three times as many students as their colleagues at MIT (see Table 4.3).

If we look at the share of doctoral students among the entire student body, we see that 19.5% of all the students of ETHZ are enrolled at the doctoral level (MIT: 26.3%). As was the case at MIT, *Fachbereiche* (Schools) have different percentages of doctoral students, depending on the professional or academic/research orientation of the *Fachbereich*[13][14]:

- Construction & Geomatics: 9.0%,

[12]ETHZ identified student-faculty ratios as an issue before, for instance in the context of the planning exercise 1992-95 (4-Year-Plan) [67]. That document, prepared in the second half of 1990, listed institutional goals to be pursued, among them the following: "Die Anzahl der Professuren ist zu erhöhen, nötigenfalls auch zu Lasten ihrer Ausstattung" (pp. 30-31). At that time, the student-faculty ratio of ETHZ was around 39:1. In the intervening 10 years, the student-faculty ratio improved to 34:1, because faculty numbers increased from around 290 to around 350 today, while student numbers and staff-faculty ratios (see Section 4.1.2) remained basically stable. In other words, the improvement of the student-faculty ratio is mainly due to an increase in resources — and not due to internal reforms or a more suitable morphology.

[13]The fifth *Fachbereich* at ETHZ, 'Other Sciences', which encompasses the Humanities, Social and Political Sciences (incl. military sciences, physical education and sports physiology), currently does not have the right (accreditation) to offer doctoral studies and issue doctoral degrees. Doctoral students working in these fields at ETHZ will have to have to have an arrangement with a second university from which they shall obtain the degree.

[14]Yearly averages of 1998-2000.

Table 4.5: ETHZ, STUDENTS PER PROFESSOR: by School ('Fachbereich') and Level of Instruction (Yearly Averages 1998-2000), based on [139]; and Tables B.2 and B.3.

	Students per Professor (by Level):		
SCHOOLS (FACHBEREICH):	Non-Doctoral	Doctoral	Total
Construction & Geomatics	34.8	3.4	38.3
Engineering Sciences	32.7	7.7	40.4
Natural Sciences & Mathematics	18.3	7.9	26.1
System-Oriented Sciences	26.5	8.4	34.9
Other Sciences	32.9	—	32.9
ETHZ OVERALL	27.5	6.7	34.1

- Engineering Sciences: 19.0%,
- Natural Sciences & Mathematics: 30.1%,
- System-Oriented Sciences: 24.1%.

4.1.2 Staff-Faculty Ratios

While student-faculty ratios belong to regularly discussed policy issues, staff-faculty ratios are — comparatively speaking — less frequently discussed: they remain, despite a certain focus on research group phenomena [83, 106], under-researched.

We have mentioned above that student-faculty ratios vary in function of a range of factors, among them: subject or discipline; and the mission, heritage or style of the institution. The same applies to staff-faculty ratios. In certain disciplines, such as the humanities, scholarly activities are mainly 'one-person shows' conducted by a professor or a doctoral student. In other fields, such as the natural sciences or engineering, investigators work more in teams. In all disciplines, administrative or technical staff is required in support of a research environment. If we look at the personnel structure in research-oriented, academic departments, we will not only find doctoral and post-doctoral students working in various positions as assistants or junior research staff, but also administrators, librarians, or technicians in support of the the required research infra-structure[15]. Staff-faculty ratios, hence, are measures of the average size of a research group in a particular environment or an institution.

In contrast to student-faculty ratios, there appear to exist no well established normative ideals concerning staff-faculty ratios. JOSEPH S. FRUTON, in reviewing research groups of the chemical and biochemical fields, refers to an "[…] optimum group size [of] about five to seven scientists [of Swedish academic groups active during the 1970s] […]" [83] (p. 231); and JOHN HURLEY concludes that "[…] small groups [of two to six people] tend to function

[15]With the increased power of computation and the widened prospects of simulation and numerical analysis, we can observe a relative reduction of technical support staff in most research environments — and a corresponding relative increase of scientific staff.

better than large ones" [106], because the communication among its members is more intimate. In larger groups, 'diseconomies of scale' become apparent: "Larger groups tend to become more structured, more rule based, more hierarchical and less flexible" (p. 126), to the detriment of science[16].

In continental Europe, research groups tend to be larger than in the British or American environment.

As in the case of student-faculty ratios, we shall find corresponding cultural differences as we look at staff-faculty ratios. In continental Europe, particularly in countries with a German higher education heritage [231], research groups tend to be larger than in the British or American environment. The reasons for these differences are unclear, but they appear to root in a different basic focus of higher education systems: research (and research education) in the case of the German university, and (general or liberal) education in the case of the British or American college (a focus partially retained by the corresponding research universities). The irony of this historical orientation is that a basic focus on education, originally adopted because of a possibly poor preparation of high-school graduates (freshmen) and retained in light of mass higher education [220, 22, 221, 101], proves now superior, as far as research output is concerned, to the original approach designed to strengthen research. We shall return to this point when we discuss productivity issues (see Chapter 7).

Issues of Measurement In order to calculate staff-faculty ratios, we have to have a clear notion of the factors making up this ratio: faculty and staff. Our notion of faculty we have already reported above: we shall count the three professorial classes only. As far as faculty and staff is concerned, we shall base our investigation on a head count, because full-time equivalents (of faculty and staff) are available for ETHZ only — and because percentages of a full time employment appear to be misleading figures in the environment of a research university: many doctoral students at ETHZ, for instance, have a 50% employment contract (for financial reasons), but work 100%[17]. In the case of other academic employees, a similar observation can frequently be made. Besides, the calculated differences between head counts on the one hand and full-time equivalents on the other are relatively small[18]. Further factors which affect the construction of staff-faculty ratios are the following:

- In order to be descriptive of the academic environment, we shall include faculty and staff in the academic departments only (and exclude those in the central administration).

[16] What we report here is not in contrast to the new developments of 'big science' (see e.g. [85]) — and not in contrast to the fact that papers in certain sub-fields of physics have several hundred authors.

[17] The average degree of full-time employment (and financial compensation), in fact, varies between close to 30% for doctoral students in the humanities, social and political sciences to close to 100% in the in the field of the computer sciences.

[18] In the case of ETHZ, where the corresponding figures are available, the overall average full-time equivalents (in comparison to head counts) are as follows: faculty (95%), academic staff (82%), research staff (71%), technical and administrative staff (81%).

Table 4.6: MIT, STAFF-FACULTY RATIOS AND RELATIVE SIZE OF FACULTY-STAFF BODY (in %): by School or Program (Yearly Averages 1999-2001), based on [139]; and Tables B.2 and B.3.

SCHOOLS (OR PROGRAM):	Staff-Faculty Ratio	Relative Size of Faculty-Staff Body (%)
School of Architecture & Planning (incl. MAS)	6:1	7.2
School of Engineering	6:1	36.2
School of Humanities & Social Science	4:1	9.4
Sloan School of Management	3:1	4.3
School of Science	8:1	37.0
Health Sciences & Technology	63:1	6.0
MIT OVERALL	6:1	100.0

- Because of different departmental obligations at the two institutions, staff structures appear to differ. For these reasons, we shall exclude Support and Service Staff at MIT when calculating staff-faculty ratios (see Table B.1).
- Staff statistics of MIT do not include doctoral students whereas staff statistics of ETHZ do include these students[19]. For the purposes of our studies, hence, we shall augment the staff statistics of MIT by the number of students pursuing doctoral studies.

MIT If we follow the principles outlined above, we count a bit more than 5,600 staff members at MIT (in the academic sector), not including some 900 faculty (see Tables B.2 and B.3). Staff-faculty ratios vary between 3:1 (in the Sloan School of Management) to 63:1 (in the Health Sciences & Technology Program), averaging around 6:1 for MIT as a whole (see Table 4.6). We saw before (Table 4.3) that the Sloan School of Management has a strong professional orientation, with comparatively few doctoral students and, hence, also a smaller staff body (as defined in the present context). At the other extreme, we see that the Health Sciences & Technology Program has a comparatively large staff, but we ought to keep in mind that faculty members engaged in that program are employed in the Schools of Engineering or Science (and 'real' faculty-staff ratios are much smaller than calculated). Overall, MIT has 6.2 staff members for every faculty member.

ETHZ In comparison to MIT, ETHZ has almost the same number of staff members, namely close to 5,400 (see Table C.2). However, as we have mentioned before, ETHZ has chosen to have a smaller faculty: circa 340 members vs. 900 for MIT. For these reasons, ETHZ has generally larger faculty-staff ratios than MIT. If we exclude the Humanities and the Social and Political Sciences (i.e. Other Sciences), where we find a staff-faculty ratio of 9:1 (and where only 4% of all staff is employed), staff-faculty ratios at ETHZ vary between 14:1 (Construction & Geomatics) and 19:1 (System-Oriented Sciences; see Table 4.7). The (comparatively) low staff-faculty ratio of Other

[19] In fact, 99% of all doctoral students are included in the staff statistics; the remaining 1% is financed by research grants not administered by ETHZ — or by no research grants at all.

Table 4.7: ETHZ, STAFF-FACULTY RATIOS AND RELATIVE SIZE OF STAFF BODY (in %): by *Fachbereich* (Yearly Averages 1998-2000), based on Tables C.2 and C.3.

SCHOOLS (FACHBEREICH):	Staff-Faculty Ratio	Relative Size of Staff Body (%)
Construction & Geomatics	14:1	14.8
Engineering Sciences	16:1	26.9
Natural Sciences & Mathematics	16:1	29.5
System-Oriented Sciences	19:1	24.8
Other Sciences	9:1	4.1
ETHZ OVERALL	16:1	100.0

Sciences is due to the disciplines included and the fact that ETHZ offers no proper degree programs in the corresponding fields. Overall, ETHZ has 15.8 staff members for every faculty member employed. Hence, staff-faculty ratios of ETHZ are roughly 2 to 3 times higher that those of MIT.

4.1.3 Graduation Rates and Time-to-Degree

Graduation rates and times-to-degree are considered indicators of educational quality. Higher graduation rates and lower times to degree are preferred, but it is recognized that these indicators are affected by a range of factors: the quality and reputation of the institution, its admission policy, grading policies and educational standards, et cetera.

Graduation Rates In the US context, graduation or completion rates play a more dominant role than in Europe, as relevant indicators, because of the prevalence of course credit systems (which ease the accounting of part-time studies) and because of comparatively elevated tuition and fees (which may have the effect to speed up studies). Since completion rates are seen as quality indicators, the Student Right-to-Know regulation of the US federal government provide that these data get published. Because of the comparatively diversified US higher education system and because of the active admission management of its higher education institutions (see section 8.2), graduation rates are frequently higher at US research universities than at corresponding European institutions (see Table A.16):

- In the case of the 34 public universities which are members of the Association of American Universities[20], six-year graduation rates (of the 1994/95 entering freshmen class) vary between 50% (University of Minnesota) and 91% (University of Virginia).

- Graduation rates of selected private universities are higher (see Table A.16), with variations between 73% (University of Southern California) and 97% (Princeton University).

[20] www.aau.edu.

Table 4.8: US DOCTORATE RECIPIENTS, PERCENT WITH BACCALAUREATE IN SAME FIELD, by Major Field (Year 2000); based on [104] (Table A-3a, pp. 72–73).

FIELD	%
Physical Sciences	62.6
Physics & Astronomy	69.5
Chemistry	73.7
Earth, Atmospheric & Marine Sciences	41.0
Mathematics	69.5
Computer Science	37.0
Engineering	74.0
Life Sciences	49.3
Social Sciences	58.3
Humanities	47.9
Total	52.3

- It is worth noting that, in all the reviewed cases (of 48 research universities), graduation rates are higher for women than for men[21], with one exception: at Princeton, the graduation rate for women is 96%, and that for men 97%.

The University of California (at Berkeley) stated in 1997 that the six-year graduation rates have increased from 68% to 80% over the previous 10 year period[22]. It is not exactly clear why graduation rates differ among institutions and what the contributing factors are which affect higher retention and graduation rates. We observe a certain correlation between reputation of the university and graduation rates, in that the 'discriminating' institutions have higher graduation rates. This is exactly the opposite of the European pattern; US institutions, in contrast, try to retain their students. A range of student-based factors contribute to retention and graduation rates: academic abilities (i.e. cognitive abilities and emotional intelligence), financial resources available, family obligations, income prospects after graduation, et cetera. But there are also institutional-based factors which play a role: a student-centered learning environment, student-faculty ratios, credit-systems and electives, advising and mentoring, et cetera.

Times-to-Degree and Cross-Over Studies Graduation rates are much more common than times-to-degree statistics, at least in the context of first degrees, and the latter might serve as a substitute for the former: within a given culture of higher education, graduation rates generally correlate (inversely) with time-to-degree indicators. In the case of doctoral studies, time-to-degree indicators appear more prevalent than completion rates, however. In the US, we observe a general prolongation of doctoral studies, by circa 20% over a 25-year period, from 6.0 years (in 1975) to 7.4 years (in 2000), years which cover the entire graduate studies period past the baccalaureate

[21] Up to 12 percentage points in the case of Clemson University.
[22] `www.berkeley.edu/news`.

[104], (Table 16, p. 46)[23]. In the physical sciences, in engineering, and in the life sciences, the corresponding figures (over the 1975–2000 period) are slightly lower:

- from 5.7 to 6.8 years (in the physical sciences),
- from 5.6 to 6.8 years (in engineering), and
- from 5.8 to 7.0 years (in the life sciences).

The prolongation of doctoral studies is perhaps a response to the increased focus on research within research universities[24].

Sizeable portions of US students pursue doctoral studies in fields in which they have not obtained their undergraduate degrees.

Regarding disciplinary orientation, we ought to refer to a phenomenon of US higher education which has no correspondence in the European Humboldtian tradition thus far, but which may grow in importance on European soil once the Bologna process (see section 8.3) takes hold. We refer to the non-linearity of US academic educational processes versus the mainly linear educational process characteristic within the Humboldtian tradition. Because of the broader focus of undergraduate studies in the US, graduate — and doctoral — studies may be pursued in a different field of study as the undergraduate degree was obtained. These cross-over studies are actually very characteristic of US higher education — and very attractive from a trans-disciplinary point of view. As Table 4.8 indicates, roughly half of all Ph.D-studies are pursued in a field which differs from the one in which the Bachelor degree was obtained, and even in highly specialized fields (such as mathematics, physics or engineering), sizeable portions of students pursue doctoral studies in fields in which they have not obtained their undergraduate degrees.

MIT and ETHZ If we look at the corresponding indicators of MIT first, we learn the following concerning graduation and retention rates:

- "For the freshmen class entering MIT in 1994, the percentage of students who received an S.B. degree within seven years of entrance — the 'graduation rate' — is 91%, the vast majority of whom finished in the normal four years (or entered combined SB/SM programs)"[25];
- the six year graduation rate for the 1995 cohort is 92%[26];
- the one-year retention rate for freshmen enrolled in the Fall of 1997 was 97%[27], and that of freshmen enrolled in the Fall of 1998 was 98%[28].

[23] To view these figures in the European context, roughly $1\frac{1}{2}$ to 2 years will have to be subtracted to arrive at figures indicative of the duration of the doctoral studies only.

[24] Nonetheless, the age of US doctorate recipients appears not elevated (see Table A.17), perhaps also due to a generally lower age at first enrollment (Table A.15).

[25] http://web.mit.edu/admissions.

[26] http://web.mit.edu/ir/cds/2002/b.html.

[27] http://web.mit.edu/ir/cds/9899cds/b.html.

[28] http://web.mit.edu/ir/cds/9900cds/b.html.

Table 4.9: MIT, DOCTORAL STUDIES, TIME-TO-DEGREE, by School, in Years (Year 1999/2000); based on Tables B.3 and B.4.

SCHOOL	Years
School of Architecture & Planning	6.5
School of Engineering	4.9
School of Humanities & Social Sciences	5.7
Sloan School of Management	3.6
School of Science	7.8
Total	5.7

Table 4.10: ETHZ, DOCTORAL STUDIES, TIME-TO-DEGREE, by *Fachbereich*, in Years (Year 1999/2000); based on data supplied by the Information Management division of ETHZ, October 10, 2001.

SCHOOL (FACHBEREICH)	Years
Construction & Geomatics	4.0
Engineering Sciences	3.5
Natural Sciences & Mathematics	3.9
System-Oriented Sciences	4.0
Total	3.8

Looking at the data of ETHZ, we rely on a paper which analyzes the freshmen cohort of 1990/91 after seven years [211][29]. The main results are the following:

- Overall, 72% of the entering students were able to complete their diploma studies within this time span; 68% finished their studies in the field they had entered at the time of enrollment (and the remaining 4% transferred to another field of study within ETHZ and graduated in that discipline).
- In most fields, drop-out rates exceeded 20%; in 5 (of 14) disciplines drop-out rates exceeded 30%, and in some (demanding) fields, drop-out rates were substantial, around 45%: in Computer Sciences, Mathematics, and in Physics. Most drop-outs occur within the first six semesters.

If we compare this performance with that of other US universities, we are not bound to conclude that ETHZ's graduation rates are greatly deficient: they are roughly in line with those of other US state universities. But if we compare ETHZ with MIT (or with other universities with high graduation rates), we observe that there is still space for improvement, along the lines perhaps of another leading state university, the University of California (at Berkeley).

[29]There are no other detailed studies available at ETHZ. The seven year period is 2 to $2\frac{1}{2}$ years longer than nominal study periods (of 9 or 10 semesters); this may roughly correspond to the 6 year period after initial enrollment at US university (where the nominal study period is 8 semesters).

In the context of doctoral studies at MIT, we lack data of completion rates or study times, but from the data available — i.e. number of students involved (Table B.3) and degrees obtained (Table B.4) — we may assess rough (and inconclusive) measures of study duration of doctoral students in that we form the ratio of these two measures: we arrive at study durations which range from 3.6 years (in the Sloan School of Management) to 7.8 years (in the School of Science); the average is 5.7 years (see Table 4.9). The data are roughly in line with the national data cited above.

If we compare the time-to-degree estimates of MIT with the corresponding data of ETHZ (see Table 4.10), we observe that ETHZ has shorter time-to-degree periods listed for doctoral studies than MIT (close to two years — or a third — shorter). We have some doubts that these figures (contained in Table 4.10) actually reflect reality because time-to-degree periods at ETHZ are counted from the time a student registers as a doctoral student. This formal registration may take place one or even two years after the student has already worked as a research assistant in the institute or laboratory in which the work on the dissertation would take place. Keep also in mind that ETHZ has no formal doctoral studies (leading to a comprehensive exam and to candidacy as a doctoral student)[30].

We shall see that MIT has a larger population of doctoral students than ETHZ (see section 5.1.3). Since time-to-degree periods and number of students are functionally related, we might conclude the following:

- If our time-to-degree estimates of MIT doctoral students are roughly correct, and if ETHZ would indeed have shorter time-to-degree periods (for the doctorate), ETHZ would have a higher turnover of doctoral students than MIT: MIT would retain its doctoral students longer — and consequently would work with more experienced students, provided study — or research — intensities are not negatively affected by longer time-to-degree periods). This might at least partially explain the observed output differentials between the two institutions (see section 6.1.3).

- Alternatively, and much more likely, time-to-degree periods differ not that markedly (for the reasons stated) — and differences in time-to-degree periods cannot be used to explain differences in bibliometric output performance. The implication would be that the number of doctoral students (at ETHZ) are in fact underestimated (by Table C.3), because they do not include the 'informal' doctoral students, and because ETHZ has not yet broadly implemented formal doctoral studies[31].

[30]Within the period of 1994-2000, roughly 80% of ETHZ's doctoral students needed at least 7 semesters to write their dissertation, roughly 60% needed at least 8 semesters, and some 30% required 9 semesters or more. Add to these the 2-4 semesters required to pass the qualifying and general examinations at MIT, the doctoral study period at ETHZ is not shorter than that of MIT's.

[31]There are some tendencies in this direction, and the Department of Electrical Engineering is leading in this respect.

4.2 Non-Academic Sector

Universities are not only composed of academic units which directly focus on education and research. In addition, they have a central administration and they have service units which support — or represent — the entire institution: libraries, collections and museums of various kinds, or offices supporting technology transfer or patenting activities. Not all of these activities can — or should — be counted as the normal overhead of academic operations and some of the units in the non-academic sector may even be self-supporting. Furthermore, each university may have its own profile of non-academic sector activities:

- some activities are taken care of by the institution itself while others are outsourced;
- administrative tasks may be centralized in one case or delegated to academic units in another.

Hence, without a detailed analysis of the various activities involved, it is clearly difficult to compare non-academic sector activities.

Nonetheless, we shall attempt to compare — in a very rough fashion — non-academic sector activities of the two institutions involved. We shall base this comparison on the Tables B.3 and B.2 (in the case of MIT) and Table C.2 (in the case of ETHZ). If we follow the same conventions for counting faculty and staff as above (see section 4.1.2), we come to the following conclusions:

- MIT has roughly 5,640 staff members in the academic sector (not including faculty) and 2,370 staff members in the non-academic sector. The staff-staff ratio (academic to non-academic) is 2.4:1. If we subsume faculty under staff, the staff-staff ratio is 2.7:1.
- ETHZ has 5,390 academic staff members (not including faculty) and 1,210 staff members in the non-academic sector. The staff-staff ratio (academic to non-academic) is 4.5:1. And if we subsume faculty under staff, the staff-staff ratio in this case is 4.7:1.

Here, we observe another major difference between the two institutions: MIT has twice as many employees in its non-academic sector than ETHZ (not counting support and service staff) — and 10 times as many faculty members in senior administrative positions. Part of the differences are due to units at MIT which do not exist in a corresponding form at ETHZ[32]. Other differences are due to differing conceptions of management and administration (professionalisation versus militia system) and because the two institutions assign differing weights to functions which are clearly within the domain of a modern research university[33].

[32]Such as the Campus Police Organization. At ETHZ, some campus police functions are taken care of by the Security Office (*Sicherheitsdienst*), but most police functions are within the responsibility of the corresponding department of the City of Zürich.

[33]The Industrial Liaison and Technology Licensing Offices at MIT, for instance, serve functions to which far more weight is assigned than at ETHZ.

New doctrines on public management call for 'slim' operations without clear conceptions of what appears necessary or 'healthy'.

While ETHZ prides itself for its 'slim' administration, austerity programs which try to mimic fitness programs may not be in the best interests of the university — and clearly not in the best interest of the society it should serve. New doctrines on public management call for 'slim' operations without clear conceptions of what appears necessary or 'healthy'. The particular doctrines are reiterated so frequently that the obsession with slimness appears to take on the form of an anorexia. Modern research universities cannot any longer simply focus on education and research, cannot foster the aura of the ivory tower. New operative functions emerge which require a professional — i.e. professionalized — staff. The implementation of the Bologna process (section 8.3.2), for instance, will imply a reform of admission processes in Europe (section 8.2), requiring staff; the same argument is valid when modern budgetary procedures are being implemented [237, 147] or when Virtual Campuses are being formed (section 8.3.2). Not only purely internal operations will be affected, but relational activities which tie the institution to its environment: extension services of various kinds and services pertaining to university-industry relations. Debates on funding issues might have to recognize this.

Chapter 5

Focus on Input

Merit in a public institution of higher education cannot exist independent of consideration of diversity.

Lani Guinier [92]

The following chapter will deal with the rudiments of the 'material' research universities work: with students, and with faculty. The chapter shall try to sketch relevant aspects of both populations.

5.1 Student Body

5.1.1 Proficiency of Students

When comparing research universities or systems of tertiary education, proficiency levels of entering students play a role. Various systems are in place designed to assure given proficiency levels, be they high school exit examinations or college entrance tests. In order to compare these various systems, we should first try to assess, in a comparative fashion, basic proficiencies as they pertain to an entire cohort of high school students. In so doing, we shall rely on the recently issued first results of the "Programme for International Student Assessment" (PISA) [172] which complements earlier results in the same area [161].

PISA: Focus and Design PISA is a well-designed and comprehensive study to assess educational skills in a range of areas: literacy in such fields as reading, mathematics, or science, or the perceived ability to use computers. It focuses on the age group of roughly the 15 to 16 year old, and the assessment covers 28 OECD nations as well as 4 Non-OECD countries. Like many studies, PISA tries to assess national averages — and hence is subject to a potential criticism we have voiced elsewhere (see section 6.1.4). Comparisons of small entities (like Luxembourg or Iceland) with large entities (like the US) are frequently fraught with methodological problems which make a comparison difficult to interpret, particularly when the small entity achieves higher scores than the large one.

Nontheless, PISA is a very valuable comparative assessment whose main results we have condensed in the Tables A.5 through A.11. PISA distinguishes four proficiency levels, spanning the range from the highest to the lowest[1]. Instead of comparing averages, we have decided to look at the two extremes: the highest and the lowest proficiency levels[2]; and within these extremes, we distinguish between below average and above average performance. The resulting tables have a 2×2-format which we collated for the following areas: reading literacy (Table A.5), mathematical literacy (Table A.6), scientific literacy (Table A.7), and perceived ability to use computers (Table A.11). Furthermore, we wanted to address the correlations between various forms of literacy and constructed 2×2-tables in that we compared above and below average performance. Three such tables are presented: reading literacy vs. scientific literacy (Table A.8), reading literacy vs. mathematical literacy (Table A.9), and scientific literacy vs. mathematical literacy (Table A.10).

Comparative Performance In the following, we shall concentrate our focus on comparing US and Swiss students. If we look at the first four of these tables, we see for instance that the PISA-results for Switzerland are classified better than those of the US in just one of the four cases: in mathematical literacy, Switzerland scores above average in the highest proficiency level as well as in the lowest proficiency level. This result is corroborated by results of the "Third International Mathematics and Science Study" (TIMSS) [161] (see Table A.12). In the remaining three comparisons regarding reading or science literacy, and in the perceived ability to use computers, the Swiss students are edged out by their US peers. In the three tables correlating literacies in reading, science and mathematics, we are confronted with tied scores, so to speak, between the two nations. While the differences between the scores of the US and Swiss students are clearly not that significant (looking at the original data of [161]), we can definitely conclude that the performance of the Swiss PISA participants is not superior to those of the US — and that the average Swiss student appears not to be better prepared academically than the average US student[3].

[1] In fact, PISA distinguished six proficiency levels: the 5th, 10th, 25th, 75th, 90th and 95th percentile. For our purposes, however, we have only looked at the four proficiency levels in between, ignoring the 5th and the 95th percentile.

[2] As defined by us.

[3] However, because of vast internal differences within the US, we may presume that one could find various regions which would significantly outperform Switzerland had these regions participated in the PISA study. Criticisms regarding these international comparative studies have been voiced before. Constance Holden cites a National Science Foundation official [105]: "If our science education system is so rotten, how come the United States still enjoys overwhelming dominance in scientific productivity?". Differences in achievement scores might be due to sampling errors which are very difficult to avoid because of differing high school participation rates and differing curricula. And lastly there is still the fundamental problem of comparing small populations (like Luxembourg or Switzerland) with the population of a large nation (like the US).

5.1.2 Admission Management

Having reviewed the general proficiency of high school students, we shall assess in the following the comparative proficiency at MIT and ETHZ in a very rough manner; background material shall be provided later on when we discuss the wider context (see Chapter 8 and, in particular, section 8.2).

Open Access vs. Active Admission Management In continental Europe most universities have an open access policy for domestic residents who are graduates of a senior high-school — the equivalent of the German *Gymnasium*[4]. In disciplines with high demand, the open access policy may be modified by policies designed to assign students to institutions on the basis of a lottery, a practice which is common in Germany (and under discussions in the US; see [92]). These lotteries attempt to distribute talent evenly, in line with an implicit policy to minimize quality differentials among universities. On the basis of such open access policies, 20 to 40 percent of the relevant cohorts enter the various university systems of Europe (see Chapter 8, and in particular section 8.1).

In the US in contrast, with its diversified higher education system, students are admitted to an institution on the basis of publicly established criteria or a selection process which takes into consideration high school grades, test scores, extracurricular activities, and the personal profile of the applicant. Public universities normally follow rules of admission which have been jointly set up by governing boards and state legislators. On the basis of such rules, a state university may generally admit all state based students which meet certain criteria, while out-of-state or graduate students may have to meet higher standards. Private universities set their own admission policies. However, public and private universities retain the freedom to admit: criteria will have to be met statistically, not in an individual case (see section 8.2).

In continental Europe, with its open access policy, a high proportion of the relevant cohort will enter universities: almost 20% in Switzerland and 25% in Germany, with an increasing tendency.

Selectivity of Institutions Having sketched the general differences between admission within the US and continental Europe, we shall try to assess the population strata entering the respective systems. Since we cannot take recourse to a general testing system in Europe or within European nations, we shall simplify the matter in assuming that we are confronted with a stratified population of aspiring students and that high school graduates constitute the 'top' stratum as far as higher education preparedness is concerned[5]. In continental Europe, with its open access policy, a high propor-

[4] Some institutes in France, for instance, require an advanced placement record, and some disciplines — in particular medicine — may practice a *Numerus clausus*.

[5] We are conscious of the fact that this assumption is very crude: a range of people who have not finished high school may be better prepared to attend college or university than others who are high school graduates.

tion of this 'top' stratum will enter universities: almost 20% of the whole cohort in Switzerland and 25% in Germany, with an increasing tendency[6].

In the US, in contrast, admission policies are partially based on test scores and if we monitor these requirements, we see that state universities will recruit their student body from a stratum as broad as that of Germany or narrower than the one we find in Switzerland. For instance, the Georgia Institute of Technology recruits students with an average test score (mathematical proficiency) corresponding to the top 93 (males) or 87 percentiles (female) [173, 60][7]. Allowing for distributions below the average, we may presume that Georgia Tech is a bit more 'selective' than the average Swiss university and clearly more 'selective' than the average German university. But some US state university systems are even more selective: the University of California, for instance, which recruits roughly the top 12% of the respective high school classes, or the Berkeley Campus which focuses on the top 8% of the corresponding cohort.

The University of California recruits roughly the top 12% of students; the Berkeley Campus focuses on the top 8% of the cohort.

If we look at the corresponding data of MIT, we are told that 91% of the entering freshmen (of the academic year 1998/99) actually submitted Standard Aptitude Test (SAT) scores [138], while the remaining were admitted on the basis of ACT scores[8]. Of those admitted on the basis of SAT scores (and other criteria), 86% had SAT (mathematics) test scores of 700 and above[9], i.e. they found themselves in the top 6.5% of the cohort (the remaining 14% had test scores of 600 to 699 and were members of the top 28% of the cohort which had taken the SAT.)[10]. If we compare these results with the observations above, we see that MIT is clearly more selective than a state university like the Georgia Institute of Technology, but it is roughly also on a par with the University of California (Berkeley), another state university.

Selectivity of MIT and ETHZ If we want to compare MIT with ETHZ, we shall have to make further assumptions which may — or may not — hold up if we were to investigate the matter further. Since there are no common entrance tests in Switzerland and because of the open admission policy prevailing, every graduate of a domestic *Gymnasium* may enroll at any public university in Switzerland, including ETHZ[11]. We have mentioned above that today (i.e. in the year 2000) close to 20% of the relevant cohort in Switzerland enter higher education at the university level. We do not know the ability

[6] In Switzerland participation rates (in the university system) have increased from 12.2% in the year 1980 to 19.4% in the year 2000; see `www.statistik.admin.ch`.

[7] These percentiles indicate the share of the test-takers which did not reach the corresponding score.

[8] ACT is a national college admission examination that consists of tests in: English, Mathematics, Reading, Science Reasoning; see `http://www.act.org`.

[9] SAT scores range from 200 to 800 (top score).

[10] In the case of SAT verbal scores, MIT is less selective.

[11] The exceptions, to our knowledge, pertain to academic programs of medicine in the German parts of Switzerland where prospective students are required to submit to an entrance test.

profile of entering students and we can only speculate whether students with higher cognitive abilities have a tendency to select natural sciences or engineering as their field of study.

We may presume that ETHZ is roughly as 'selective' as the Georgia Institute of Technology, but if processes of 'self-censorship' play a role, ETHZ may be (implicitly) more selective, i.e. on a par with institutions of the University of California system or even on a par with Berkeley or MIT: cursory evidence regarding high school grades indicates that students at ETHZ belonged to the top 50% — or even the top 30% — of their high school classes. Assuming that the roughly 20% of the cohort who attend senior high school (i.e. *Gymnasium*) are at the same time the the top 20% as far as cognitive skills are concerned (an assumption which is open to debate), this would translate that the top 10% — or even the top 7% — of the cohort enroll at ETHZ.

If processes of 'self-censorship' play a role, ETHZ may be as selective as the University of California system or be even on a par with Berkeley or MIT.

Reliability of Tests Having said all this we should discount our premise that test scores reliably measure talent or ability: they are indicators of proficiency, indeed, but we have also ample empirical evidence that test scores, achievement in school and success in life are different matters. In fact, studies indicate that the predictive power of SAT (or other) scores is limited: correlation between SAT scores on the one hand and college grade point averages on the other normally fall in the range of 0.3 and 0.5 (depending on the study) [30]. Reliance on test scores may favor children of well-to-do families and, as Lani Guinier remarks, "SAT's correlate less with college students' first-year grades than with their parents' or their grandparents' socioeconomic status". Furthermore, we know that responsible commitments and contributions to society — as parents or professionals, or in the fields of leadership or public service — depend on a "range of intelligencies — including personality factors such as drive, motivation, creativity, and problem solving skills", most of which are not tested, are difficult to test, and bear scant relations to factors actually tested [92].

5.1.3 Composition of Student Body

Apart from assessing the cognitive proficiency of entering student classes, we may want to sketch a picture of the composition of the student body at the two institutions. We shall not be in a position to provide details regarding the socio-economic background of the students or their extra-curricular orientations, information which may be available at an admission office. Instead, we shall focus on the rudiments we are in position to report on: non-doctoral vs. doctoral students[12], disciplinary orientations, and percentages of women, minority students (MIT only) or international students.

[12] A comparison of undergraduate vs. graduate students is difficult because of differences in the curricular programs, differences which may be lessened or eliminated once the European Bologna process is further on its way; see section 8.3.

Table 5.1: SHARE OF PARTICULAR STUDENT POPULATIONS (in %): by Institution (Years 1999 [MIT] and 2000 [ETHZ]), based on and Tables B.3 and C.3, and http://web.mit.edu/registrar/www/stats/ and www.imc.ethz.ch/stud/200012/welcome.html.

STUDENT POPULATION:	MIT (%)	ETHZ (%)
non-doctoral students	74	81
doctoral students	26	20
Architecture & Engineering	58	49
Sciences	26	44
Social Sciences & Humanities	16	7
women	33	26
minority students	27	n.a.
international students	25	16

Doctoral Students The primary, comparative data are contained in Table 5.1. From this table, we can see that MIT has a larger share of doctoral students (see section 4.1.1):

- The percentage of doctoral students (at MIT) is particularly high in the School of Humanities & Social Science (51%) (see Table B.3) and in the School of Science (47%), whereas the Sloan School of Management has a distinct professional orientation (7%).
- In contrast, ETHZ has its highest shares of doctoral students in the fields of Natural Sciences & Mathematics (30%) (see Table C.3) and System-Oriented Sciences (24%), and its lowest shares in Construction & Geomatics (9%)[13].

If we look at the disciplinary orientation of the student body, we see that MIT has a strong focus in Architecture & Engineering (see Table 5.1), and a relatively strong focus in the Social Sciences & Humanities, whereas the student body of ETHZ is equally divided between Architecture & Engineering on the one hand and the Sciences on the other.

Women and Minorities Concerning the share of women among the students, MIT again shows higher shares (see also Table A.17):

- In MIT's School of Architecture and Planning (including Media Arts), the women make up 37% of total enrollment (1999-2001 yearly averages); in the School of Engineering, the corresponding share is 24%; in the School of Humanities, Arts, and Social Sciences 39%; in the Sloan School of Management 27%, and in the School of Science 37%.
- At ETHZ, the share of woman in the fields of Construction & Geomatics (including Architecture) is 32% (the percentages pertain to the year 2000); in Engineering Sciences 9%, in Natural Sciences & Mathematics 25%, in System-Oriented Sciences 44%, and in Other Sciences 44%.

[13] In Other Sciences ETHZ lacks the accreditation to confer doctoral degrees.

Concerning minority students there are no corresponding figures for ETHZ, of course[14]. The percentages at MIT are lower than at the University of California (Berkeley), for instance (see Table 8.3), but they are still sizable.

International Students Lastly, we have comparative figures on international students. In the US, engineering and natural sciences are particularly attractive for international students (see Tables A.18 and A.19): in the natural sciences, roughly 40% of all US doctoral degrees conferred (in 1995) go to international students, and in engineering the corresponding figure is even higher (see also Table A.17). Some nationals, such as those of China and Taiwan, have profited greatly from educational opportunities in the US (Table A.19). This enormous contribution to international education by US higher education is rarely recognized, perhaps because it is primarily seen as taking place in the US interests. In any case, the figures attest to the vitality and attractiveness of the US higher education system.

Looking at the figures of our two institutions, we see that among the undergraduates of MIT, international students make up 6% of the corresponding student body, and 37% among the graduate students (1999-2001 yearly averages); their combined percentage of the total student population is 25% (Table 5.1). International doctoral students make up 11% of MIT's student body (or 37% of MIT's doctoral students). If we compare these figures with ETHZ, we observe that 16% of the student body are listed as international students (Table 5.1), and 46% of the doctoral students (year 2000)[15].

5.2 Faculty

Having compared admission processes of students and the compositions of the respective student bodies, we shall try to assess here recruitment and employment policies as they pertain to faculty. We shall do this in the most cursory fashion, naturally, since the purpose of this Report is not to redesign these policies.

Recruitment Policies If we look at the recruitment of faculty first, we may be confronted with two options which we may characterize, informally, as the "Harvard approach" versus the "MIT approach"[16]. Harvard University is known to attract an excellent faculty which is frequently recruited after the respective individuals have already achieved academic recognition or fame elsewhere. Because of Harvard's wealth, the approach to recruit senior faculty at other leading research universities — and at higher than average salaries — is clearly feasible (see Table A.4); and Harvard is strong in the humanities and the social sciences, among others, i.e. in fields which do not require expensive laboratories and equipment. The appointment of

[14]'Minority' at MIT refers to African Americans, Mexican American, Native American, Other Hispanics and Puerto Ricans.

[15]Since MIT and ETHZ define graduate levels differently — thus far at least —, we can only doctoral and non-doctoral level studies.

[16]The labeling of these two options was common at ETHZ when discussing various faculty strengthening strategies.

senior faculty has the advantage that the visibility of a particular field can be quickly improved and changes in academic orientation and research can become effective sooner.

In the past, ETHZ pursued a 'Harvard approach' to faculty recruitment, perhaps in a more stringent fashion than Harvard itself.

In the past, ETHZ pursued a Harvard approach, perhaps in a more stringent fashion than Harvard itself[17]. Until very recently, permanent faculty positions were offered to senior faculty only, at the rank of Associate Professor (*ausserordentliche Professur*) or Full Professor (*ordentliche Professur*). The rank of Assistant Professor (*Assistenzprofessur*), itself only a few decades old, was not used as a tenure track and Assistant Professors employed at ETHZ normally had to move to another university to continue their career. In the past, at least, ETHZ showed little interest in the rank of the Assistant Professor and the tenure track — the path to permanent employment. The reasons for this disinterest can be traced to the morphological ideal and to the notion that, in the engineering sciences at least, the ideal senior faculty member was a person likely recruited from a position in industry, not in academics. This person was said to have a vision of what was required in the various segments of the economy; he or she had a good notion of the engineering practices and markets students had to be prepared for; and presumably the person had the connections to establish the required university-industry links.

In pursuing this approach, ETHZ was quite successful in assembling an international faculty of high quality: roughly 40% of ETHZ's faculty are foreigners recruited from abroad, roughly 30% are Swiss recruited from abroad (i.e. mostly Swiss holding faculty positions at foreign institutions), and the remaining 30% — Swiss as well as foreigners — are recruited from within Switzerland[18]. In recent years, however, pressures have mounted to reasses ETHZ's appointment policy and to recruit faculty on the basis of a revised rationale, implying a shift to a policy to recruit faculty which we have subsumed under the "MIT approach": to recruit a fair portion of faculty early, as Assistant Professors, and to retain and promote them to a tenured position[19].

[17] LAWRENCE SUMMERS, the new President of Harvard, appears to redefine the old appointment policies to conform more to those of MIT; see [226].

[18] This statistics was assembled a few years ago, but cursory evidence indicates that the pattern remained rather stable in recent years. Currently (year 2000), 50% of ETHZ's faculty are foreign subjects. More detailed studies would be required to assess the 'true' international character of ETHZ vis-à-vis other European or US institutions, including MIT: a fair number of faculty members at ETHZ are from Germany, for instance, a neighboring country. More important than the citizenship of faculty is their international experience during their years of graduate and post-doctoral studies or their appointments as faculty members.

[19] An analogy to the MIT versus Harvard approach to faculty recruitment can be found in the world of soccer, for instance: here we might speak of the recruitment policies of Ajax Amsterdam, a club pursuing an active policy to develop their own cadre of young players, and other major soccer clubs which rely primarily on the transfer of players to form their teams.

Reassessment of Employment Policies A number of developments at ETHZ — and in Europe — have cleared the path to such a reassessment:

- the perceived bottlenecks in the career paths of aspiring young scholars;
- the more assertive role of women and society's efforts to fight discrimination in various forms;
- the increased research-intensity of engineering; and
- doubts regarding the effectiveness of the traditional structural — or hierarchical, morphological — setup of faculties or departments.

The first point mentioned, the increased awareness of a lack of proper career prospects for young researchers and prospective faculty members, has been widely discussed in Europe [15, 28, 132, 167] but sustaining reforms, i.e. reforms which significantly affect the direct career prospects of post-doctorates, have yet to be initiated (see Chapter 8). Second, to enhance the position of junior researchers and that of women among the faculty, funds have been earmarked for some time by the Swiss National Science Foundation, for instance, to finance junior faculty positions: so called *Förderprofessuren* at the rank of Assistant Professors, based on the stipulation that a third of these positions be reserved for women. These faculty positions help to gradually transform the cultural climate within the respective domains and may hopefully slowly pressure the institutions to appoint more women as faculty — and more faculty in general.

Pressures have mounted to reassess ETHZ's appointment policy and to recruit a fair portion of faculty early, as Assistant Professors, and to retain and promote them to a tenured position.

The third point mentioned above refers to a phenomenon which has been visible for some time, namely a blurring of the boundaries between basic research on the one hand and applied research on the other. This phenomenon has far-reaching consequences for science and engineering (and for the interplay of the two domains)[20]. We increasingly observe that we have often difficulties distinguishing between the domains of science and engineering, and we observe that the intersections between science and engineering gradually become more important. The consequence of processes such as these is that 'classical' engineering fields are gradually transferred from institutes of technologies (such as ETHZ, MIT) to less research-intensive institutions (such as *Fachhochschulen*). Conversely, fields of engineering retained or developed at research-intensive institutions become increasingly research intensive themselves. Hence, other career paths for engineering faculty come to the foreground and the tenure track for junior faculty members (Assistant Professors) is more and more a viable alternative to the appointment of senior faculty recruited from industry.

[20]As well as for the implementation of diversity in higher education; see e.g. section 8.2, Binary Systems.

The three developments just mentioned — i.e. the fight for a better career advancement, for less discriminatory faculty appointment practices, and for a new self-assessment and understanding of engineering education and research — are bringing about also a reassessment of the two faculty appointment practices introduced initially, the “Harvard approach”, as we called it, versus the “MIT approach”. Increasingly, the “MIT approach” gains support, and for good reasons. In the research-intensive fields of science and engineering, junior faculty need a proper research infrastructure and equipment which is frequently research-specific and not easily transferable. To setup a position of Assistant Professor, often larger investments become necessary and the subsequent integration of the junior faculty member into the department and respective research environment requires large inputs of time and effort on the part of other faculty. Hence, it is quite natural that an institution like MIT tries to protect this ‘investment’ by trying to hold onto the individual, provided the person in question is qualified for the position and fits into the setting. To hold onto qualified junior faculty members is clearly cheaper than to appoint senior faculty members of repute from the outside.

Lastly, we shall have to focus on the forth point mentioned above. We shall deal with this point more closely in chapters 7 and 8.

Composition of Faculty We have mentioned (in Chapter 2) the fact that MIT has a faculty roughly three times as large as that of ETHZ, while student and staff numbers (at least in the academic sector) are roughly of equal size. We have dealt with the details of this fact in chapters 4 and 7. Two aspects may be of interest in the present context: the relative shares of tenured faculty members at the two institutions, and the relative shares of women among the faculty.

Tenure is a concept which is just about to be introduced in Switzerland, and the concept is not identical to the one found in the US. Strictly speaking, there is no tenure (planned) in Switzerland, but for practical purposes we shall count senior faculty positions in Switzerland — i.e. positions at the rank of Associate Professor and Full Professor — as tenured positions. If we look at the share of Assistant Professors among the faculty, MIT has roughly 19% in that category[21], while ETHZ has 15% [69]. At MIT, there are also non-tenured positions at the rank of Associate Professors: 9% of the faculty fall into this category. How do we assess these shares?

Let us assume a thirty year (average) lifetime of the professorial state (from the initial appointment as Assistant Professor to the eventual retirement as Full Professor), and let us further assume that tenure be granted (to some faculty) 6 years after initial appointment. If we further assume that no tenured faculty member leave the institution prior to retirement, 25% of the senior faculty would have to be replaced within each 6 year period (assuming a steady-state situation). This replacement can take place through offerings of tenure or through the appointment of senior faculty from outside the institution. MIT allegedly offers roughly a third of its non-tenured faculty members tenure [64]. On the basis of these (unverified) assumptions, MIT would replace close to 40% of its senior faculty population through the

[21] `http://web.mit.edu/ir/pop/faculty/`.

tenure process (and roughly 60% would be based on appointments from the outside)[22]. ETHZ, in contrast to MIT, has no longstanding tenure policy, but if ETHZ would want to replace an equal share of its senior faculty through the tenure process of junior faculty, ETHZ would need a larger share of Assistant Professors or would have to rely on a far higher tenure rate[23].

If we turn to the second issue, the relative share of women among the faculty, we see that MIT has circa 16% women overall [141] and ETHZ has 7% [69]. While MIT has higher shares of women faculty than ETHZ, both shares are in fact low and characteristic for technically oriented institutions. It is a well observed phenomenon that the share of women declines as one climbs the career ladder in academia, and it is unclear in what ways participatory rates of women directly affect research performance. But the policy issues, the indirect effects, and the economic issues appear clear: equal opportunity visions demand that the share of women among faculty be raised, role modeling can only happen when role models are around, work environments are probably best when both men and women serve in positions of responsibility, and modern economies cannot forego the talent, spirit and contributions of half of mankind. These issues will have to be addressed in other contexts, not here. Because we focus in this study not on gender issues but on structure and culture as they relate to performance, we may only speculate to what extent quality may imply equality (and vice versa) and to what extent women may serve as institutional quality indicators, as — metaphorically speaking — the trout to test the quality of water.

Work environments are probably best when both men and women serve in positions of responsibility; modern economies cannot forego the talent, spirit and contributions of half of mankind.

[22]A detailed modeling of this process might rely on Markov-Chain theory.

[23]A tenure rate of 50% would replace roughly 30% of ETHZ's senior faculty (at current numbers of faculty). For quality reasons, it appears perhaps preferable to raise the number of Assistant Professors in order to assure a more discriminatory appointment at the senior level.

Chapter 6

Focus on Output

Never let schooling interfere with your education.

Russel L. Ackoff [1]

In the following chapter, we shall be concerned with output-indicators of a research university: bibliometric indicators (i.e. publication and citation counts), prizes and honors, and — briefly — degrees. When assessing performance, the fist two classes of indicators are used as proxy-measures for what we intuitively view as institutional 'quality'. In other words, we presume that proxy-measures serve as operational definitions of our notions of quality [182, 76] and we might observe high correlations when comparing proxy-measures on the one hand with intuitive quality assessments on the other [164]. Although these indicators have a clear research focus, we view them also as indicators of the teaching-learning nexus (in a research university). In addition, we shall briefly directly compare numbers of doctoral degrees (see also Chapter 4).

For technical reasons, we shall not be concerned with what is frequently referred to as 'outcomes', i.e. career patterns of alumni (other than in the context of section 6.2), spin-off companies, or the economic impact of institutions [157, 188, 117]. We should also note that not all outstanding achievements of a technical university show up in the form of publications and Nobel awards: take for instance Christian Menn, faculty member (emeritus) of ETHZ's Department of Civil Engineering and designer of the new Charles River bridge in Boston[1], or Herzog & de Meuron, faculty of ETHZ's Department of Architecture, who were awarded the Pritzker Prize last year[2].

6.1 Bibliometric Indicators

We shall be concerned with two classes of bibliometric indicators which are widely used in the assessment of research output. The first assembles indices based on the number of publications produced by a research unit (or by an individual — or even a nation) over a given time period, i.e. crude

[1] `www.news.harvard.edu/gazette/2001/03.01/07-bridgedesign.html`.

[2] The Pritzker Prize is considered the Nobel Prize of Architecture.

measures of output. The second class groups indices based on the number of citations generated by these publications, i.e. measures of 'reception' (or 'impact').

In particular, we shall use two indicators to measure research output at institutions (for a definition of indicators used see [33] and [35], and for the indicators themselves, see Appendix D.1):

- the total number of publications produced by the institutions, over a given time period, and by field (i.e. subject matter or discipline defined by journal categories as specified by the Institute of Scientific Information), and
- the relative citation index (RCI), calculated for the corresponding time period, and by field.

6.1.1 Publications and Impact

Publications The first measure is a rough index of output. The count of publications is not affected by the quality of the journals in which the papers where published nor by the quality of the papers themselves. The measure itself, i.e. the publication count, is functionally related to a range of factors: to the number of researchers involved, to the field under consideration, and to the local style or mode of work. In a given field, the number of publications will normally vary in accordance with the number of researchers employed, but local styles, abilities, know-how, et cetera, play a role. If publication output (per person, period, and in a given field) is higher at one institution than at another, we are tempted to conclude that productivity at the first institution is higher than at the second[3]. But we may also argue that because of increased pressures to publish, because of a possible "publish-or-perish syndrome", publication counts at the first institution are higher than at the second while the quality of output is adversely affected: the output is repetitious; the same ideas, similar concepts or experiments get published not only once, but several times; and citation rates per paper drop.

Citations The second index is a measure of reception (or impact). It is based on the frequency with which publications are cited by other authors, but no direct conclusion can be drawn on the basis of the citation count concerning the reasons for which particular publications are cited. There are a range of reasons to cite: e.g. to refer the reader to studies of authors whose ideas are expanded on, or on which the particular publication is based; to refer, in general, to the history of ideas; or to refer to concepts, models, ideas, et cetera, one wants to argue against; or even to ridicule. Hence, citation counts are descriptive of the attention publications receive by other authors — for 'good' or for 'bad' reasons. While citation counts of specific papers — or of publications by individual authors — generally require some interpretation concerning the 'reasons' of citations, citation counts referring to

[3] An analogous argument can be made if we look — comparatively — at the research production of entire nations.

Table 6.1: IMPACT ANALYSIS OF FIVE NATIONAL MEDICAL R&D SYSTEMS: Compensation Factors, based on [228].

	Period:		
NATION:	1981-85	1988-92	1994-98
France	1.33	1.15	1.12
Germany	1.27	1.14	1.11
Switzerland	1.22	1.10	1.08
UK, US	1.00	1.00	1.00

entire departments, school or universities are generally taken at face value: the higher the citation count, the higher this reception measure, the better.

Language Biases While citation counts are generally interpreted as a rough measure of quality (of papers cited), there is also some evidence that citation counts are subject to language biases [227, 228, 178].

Language orientation may be indicative of an international vs. 'local' discourse.

Language biases have the effect that non-English language papers are cited less frequently than papers published in journals using English as their primary language (because they reach a smaller audience). In that way scientists of continental Europe, for instance, are in a comparative disadvantage because they publish part of their work in non-English language journals. How significant is this effect? According to VAN LEEUWEN et al. which provide estimates of this effect in the medical field (over the period from 1981 to 1998), impact is roughly 10% to 30% higher if one excludes non-English language journals (see Table 6.1). But we also see that the language bias diminishes as we look at the more recent history, presumably because continental European authors publish more frequently in English: whereas in the period of 1981-85 compensation factors ranging between 1.33 (France) and 1.22 (Switzerland) were necessary to eliminate language bias in that field, the corresponding necessary compensation factors in the most recent period 1994-98 were substantially smaller, ranging between 1.12 (France) and 1.08 (Switzerland).

It remains an open question to what extent these findings are characteristic for other disciplinary domains as well. We may presume that many scientific fields are characterized by similar language orientations, particularly as we look at the natural sciences and engineering (the subject matters focused on most prominently in this Report). But it is clear that we shall experience increased language biases as we look at publications of the social sciences or the humanities. The language orientation of authors, however, does not only affect reception or impact factors: it may also be indicative of the extent to which specific author groups participate in an international scientific discourse or — alternatively — in a 'local' discipline. It is clear that scientists whose native language is not English view the development of English as a *lingua franca* with some reservation. But if author groups of certain disciplinary fields show a distinct proclivity to use their own native

— i.e. non-English — language, they lack international visibility and we may surmise that there is something 'wrong' with the field under consideration[4].

Classification of Research Production Having commented on two measures used to characterize research output, we shall look at the interplay of these measures, publication counts on the one hand and citation counts on the other. We may conceptually think of a 2×2-Table (see Table 6.2) which should enable us:

- to compare institutions under consideration (and their disciplinary fields or subfields) — or even nations;
- to identify dominating positions (of fields etc.); and
- to speculate about the question, referred to above, to what extent the "publish-or-perish syndrome" may be linked to a comparatively lowered quality of publications.

As we look at the Table 6.2, we can identify four types of research. Research, if it is undertaken at all, should have an impact (eventually) and should be well received and recognized. If we benchmark research (of individuals, institutions or nations), we would like to see the evaluated research (in comparison to the benchmarking standard) of Type 3 or 4. But quality alone (as measured by citations) may not be of concern to us: quantity (as measured by publication counts) matters as well if we are concerned with productivity. From this perspective, our aim may be Type 4 research. This type of research is frequently characterized by a certain degree of redundancy which forms a necessary ingredient of the scientific enterprise: experiments have to be duplicated and colleagues ought to be accessible whose research fields are not too far removed from one's own. If we are confronted with Type 2 research, we conceivably have the resources to transform this research gradually, through the infusion of new talent, to increase quality (in order to establish Type 4 research); alternatively, we may be in a position to reallocate resources to fund new research groups.

6.1.2 MIT's Position within the US

Before we embark on a comparison between MIT and ETHZ regarding research output, we shall sketch MIT's research position within US academia on the basis of a comparative study issued by the National Research Council (NRC) [164][5]. This will enable us (at least tentatively) to assess ETHZ's relative position as well (vis-à-vis other US institutions).

[4]The field of *Raumplanung und Raumordnung* in German speaking countries may serve as an example. Despite clear indications that this discipline remained ideologically infected past World War II [126, 162, 185], the discipline retained her compromising name and a strong 'local' culture. Non-systematic observations at ETHZ over more than a decade indicate that the rate of international (i.e. English or French, and peer-reviewed) publications by corresponding faculty and social scientists was extremely low, to the detriment of scientific development (of their own and that of others).

[5]These studies are issued roughly every decade. The study cited is the last available.

Table 6.2: Classification Scheme of Research Production of Universities.

		Publication Count	
		low	high
Citation Count	low	Type 1: Marginal research, perhaps not yet established	Type 2: Redundant production, perhaps inconsequential
	high	Type 3: Established research, high quality output	Type 4: High research productivity and high quality output

As we have indicated before (in Chapter 3), MIT offers a wide range of programs, not only in the natural sciences and engineering, but also in other fields (e.g. humanities, social sciences, architecture, etc.). Twenty-three of these programs have been evaluated as part of the NRC-study (see Table D.1). Every single one of these programs is rated to belong to the first 15 nationally: 17 (of 23) programs are rated to belong to the first 3 nationally; an additional 3 programs are rated to belong to the first 10; and the remaining 3 are rated to belong to the first 15 programs nationally[6]. Details are provided for eight exemplary fields, four in engineering, and four in the natural sciences (see Tables D.2 through D.9).

The NRC-study is a rich source of information: programs are evaluated by peers (on a scale ranging from 0 to 5) and other data is provided (publication and citation rates, size of faculty, number of doctoral students, etc.). As we analyze this information, we observe particular relationships [164] (Appendix O, pp. 427–468; and Tables D.2 through D.9), such as:

- quality assessment is loosely correlated with the size of the faculty (the correlation coefficients range from 0.14 [linguistics] to 0.78 [physics], but most relevant coefficients range from 0.5 to 0.7); and
- publications are coupled to citations (correlations of 0.61 [economics] to 0.93 [chemical engineering, electrical engineering]).
- We see that faculty for the various programs (in the top quarter of the programs assessed) normally number between 20 and 60 individuals (and that top quarter programs have a faculty that is 2 to 5 times larger than corresponding bottom quarter programs).
- Publication counts (per faculty member) of top quarter programs are higher than those of bottom quarter programs by a factor of 2 to 3, and corresponding citation counts (per faculty member) by a factor of 3 to 8.

[6]Depending on the field, the NRC-study evaluated roughly the most prominent 40 to 170 doctoral programs. Keep in mind that there are over 3,900 higher education institutions in the US, of which close to 7% (i.e. 261) are classified as Doctoral/Research Universities; see [204].

6.1.3 Bibliometric Indicators: MIT versus ETHZ

As we move our attention to a direct comparison of MIT and ETHZ, we shall base our observations on information supplied by CEST [35], publication and citation counts (see Tables D.10 to D.14). In evaluating the results of such a comparison, we have to keep in mind that MIT is slightly larger than ETHZ and that ETHZ is confronted with a possible language bias. CEST evaluated 25 major fields (coded f01 to f25 — see Table D.10) and a range of subfields[7] covering the various disciplinary domains of MIT and ETHZ. Fields and subfields, as defined, bear no direct correspondence to programs or departments of the two institutions: they correspond to comparable journal classes as defined by the Institute of Scientific Information (ISI). Publication and citation counts refer to one or the other institution as a whole — and not to administrative units within institutions.

- Of the 25 major fields assessed, MIT has higher publication counts than ETHZ in 19 fields (the exceptions are the fields of 'Agricultural Sciences', 'Chemistry', 'Plant & Animal Science', 'Ecology & Environment', 'Microbiology' and 'Pharmacology' where ETHZ shows higher publication counts; see Table D.10).

- Among the fields where ETHZ edges out MIT, 'Chemistry' is very strong in both institutions. Chemical Engineering is one of these fields where ETHZ has higher scores regarding publications and citations (Tables D.11 and D.14), but chemical engineering is also the field where MIT is rated number two in the US (Table D.3); by transitivity, hence, ETHZ would have to be counted as an institution equivalent to the very leading universities in the US — i.e. in rank one or two!

- In those fields where MIT has higher publication counts than ETHZ, MIT normally dominates ETHZ by factors of 2 to 10; the exception are the fields of 'Geosciences', 'Biology & Biochemistry' and 'Neuroscience', fields which are strong at ETHZ as well.

- If we look at counts of publications alone and observe how many fields or subfields are sustained at a given level of publications' output, we see that MIT sustains roughly 35% to 140% more fields than ETHZ at a given output level (see Table D.12). If we set the required output level at 10 publications per annum, MIT counts 48 fields with such an output, and ETHZ has 35; if the level is set at 100 publications per annum, MIT has 9 such fields, ETHZ 5; and if the output level is set at 200 publications per year, MIT has two such fields, and ETHZ one.

- If we look at citations, MIT's position vis-à-vis ETHZ is even stronger than in the case of publications. In four of the five cases where ETHZ edged out MIT as far as publications were concerned, MIT has now higher citation impacts (see Table D.13)[8]. Furthermore, in the remaining fields (i.e. where MIT has higher publication counts than ETHZ), MIT retained its dominance.

[7] We make use of 51 of those.

[8] The exception are the Agricultural Sciences where MIT is not really active.

Table 6.3: MIT versus ETHZ, Research Fields (Subfields) Classified by Publications and Citation Impact.

		Publications	
		lower at MIT (higher at ETHZ)	higher at MIT (lower at ETHZ)
Citation Impact at MIT (vs. ETHZ)	lower	Chemical Engineering Spectroscopy, Instrumentation, Analytical Sciences	Optics & Acoustics Organic Chemistry & Polymer Science
	higher	Chemistry Inorganic & Nuclear Chemistry Physical Chemistry & Chemical Physics Plant & Animal Science Ecology & Environment Microbiology Pharmacology	Life Sciences Physical, Chemical & Earth Sciences AI, Robotics & Automatic Control Civil Engineering Electrical & Electronic Engineering Instrumentation & Measurement Mechanical Engineering Materials Science & Engineering Mathematics Applied Physics, Condensed Matter, Materials Science Nuclear-, Particle-, Theoretical- and Plasma-Physics Astrophysics Earth Sciences Chemistry & Analysis Biochemistry & Applied Microbiology Biochemistry & Biophysics Cell & Developmental Biology Molecular Biology & Genetics Neuroscience

- Looking at the details (Table D.14), we see that in one field MIT has a negative Relative Citation Index (RCI) — which indicates lower than (world) average performance —, namely in the subfield of 'Engineering Management, General Engineering', whereas ETHZ has four such areas: 'Food Science & Nutrition', 'Mechanical Engineering', 'Animal Sciences', and 'Entomology, Pest Control'.

If we juxtapose MIT's and ETHZ's output, we are confronted with Table 6.3 (fashioned in analogy to Table 6.2)[9]: the table lists MIT's position relative to that of ETHZ (i.e. it is formulated from the point of view of MIT, with ETHZ's position as the reference point, as the benchmark). The table lists all the fields in which both institutions are active (at reasonable levels). The table shows that among the 24 fields listed, 20 fields of MIT are of either Type 3 or 4 (16 are of Type 4).

[9]Keep in mind that Table 6.2 is formulated to benchmark the output of institution against a reasonable (average) standard, not to pit two leading research institutions against each other.

6.1.4 National Comparisons

The clear dominance of MIT vis-à-vis ETHZ as far as research productivity indicators are concerned might come as a surprise to those who had been observers of national benchmarks. Readers of national benchmarking reports have come to expect a leading role of Switzerland — and by implication also of Swiss institutions — in various context of the science enterprise. If we look at the share of publications per inhabitant, Switzerland is listed as number one among the nations [239] (p. 36); if we look at doctoral awards in relation to the age cohorts, we see the same picture [49] (p. 68). If the overall impact of publications is our focus, Switzerland is again listed in the first place [33, 239] (p. 45). If we are concerned with the impact in specific fields, Switzerland is listed in first place in the following ten fields: botany and zoology, chemistry, immunology, engineering, material sciences, molecular biology and genetics, multidisciplinary sciences, ecology and environmental sciences, pharmacology, and physics — and in two fields Switzerland places at a very close second: in biology and biochemistry, and in neuroscience [200] (p. 28).

Readers of national benchmarking reports have come to expect a leading role of Switzerland — and by implications also of Swiss institutions — in various contexts of the science enterprise.

These excellent relative positions of Switzerland in relation to other nations might have deterred a critical reception of the relevant data and may have blinded potential investigators. To compare small entities (like Switzerland) with large ones (like the US) is inherently difficult and perhaps misleading, particularly if averages are compared. If we compare the US with individual European nations, we ought to keep in mind the diversity we find within the US. Not the average US performance should be a benchmark for a small European nation of ambition, but the performance of 'peer regions' within the US, e.g. California, Massachusetts, the Research Triangle Area in North Carolina, regions in Georgia and Texas, et cetera[10]. Better yet, we should concentrate on comparing individual institutions, a path pursued now by CEST.

If we look at individual institutions, we observe significant output differentials. As we have seen when we tried to assess MIT's research output within the US (see section 6.1.2), output differentials of research universities within the US are quite significant. If we focus on publication counts, top quarter doctoral programs have publication rates which are 2 to 3 times higher than bottom quarter programs, and if we look at citation counts we see differentials between the top and the lowest layer of factors between 3 to 8 (depending on the program). Since MIT is a leading institution within the top quarter of programs, MIT is normally by factors better than the average program. And if the average US program is the benchmark for Swiss universities, the wrong targets have been chosen.

[10] The corresponding statistics may be difficult to find, because most organizations charged with comparative analyses — like e.g. OECD, Eurostat —, publish data based on national entities only.

6.2 Prizes and Honors

6.2.1 Prizes as Indicators

Because we hypothesize that performance differentials are frequently due to cultural differences which in turn affect research environments and organizational setups (see Chapter 7), we want to check whether the impression derived from bibliometric analyses holds up when we look at the distribution of scientific awards: the Nobel and Kyoto prizes, and the Fields medal. We shall use the data of the awards primarily because all three are respected, because they have a truly international reach, and because it is reasonable to assume that the geographic distribution of these prizes is indicative — or representative to some extent — of the research enterprise in general.

MIT is normally by factors better than the average US program. And if the average US program is the benchmark for Swiss universities, the wrong targets have been chosen.

Making these assumptions, we shall also have to deal with the question to what extent awards like these are free of bias. Harriet Zuckerman, in her excellent study on Nobel laureates, raises this question [245]. There are perhaps two possibilities for biased awards: the influence of past laureates on the final award and the prior selection of candidates, favoring their own students or collaborators; and the workings of what Robert K. Merton has called the 'Matthew Effect' which "[...] consists of the accruing of greater increments of recognition to scientists of considerable repute and the withholding of such recognition from scientists who have not yet made their mark" [153] (chapter 20 and p. 446 there). Both possible biases are part of any evaluative work where — or even while — we make use of experts, whether we assess doctoral programs [164] or individuals.

Indeed, many Nobel laureates, for instance, worked with older laureates, perhaps half — or even some two-thirds [245] (p. xxi) of the entire population. Is this now proof of a bias? Harriet Zuckerman cites Nobelist Paul Samuelson[11]: "I can tell how to get a Nobel prize. One condition is to have great teachers". Perhaps, Nobelists are great teachers; perhaps, great teachers produce laureates in that they transmit their insight and their craft in doing research to the next generation. However, the evidence that laureates push their own candidates unduly, that is beyond the limits of their accomplishment and talent, is slim. Keep in mind that laureates constitute generally a small portion of those involved in the selection process. True enough, there are others worthy of these awards. But because we are not concerned with individuals, the question would be whether possible biases would significantly affect the institutional distribution of the awards or the grouping of the institutions to which awards were accorded. Now, such significant biases appear not to be present.

Because we study cultural differences, we shall have to identify the location of the laureate. But which location? The place of birth or basic school-

[11] Nobel Prize in Economics, 1970; from Samuelson's acceptance speech.

Table 6.4: NUMBER OF NOBELISTS, by fields (Chemistry, Physics, and Physiology or Medicine [1945-2001], Economics [1969-2001]) and region.

	Region:	
FIELDS:	US	Rest
Chemistry	48	47
Physics	72	49
Physiology or Medicine	79	50
Economics	35	14

ing? The place of Ph.D-studies? The location where the relevant research was conducted? The place of appointment at the time when the prize was awarded? While we studied the data, we became conscious of the complexity of the questions involved. Perhaps, all these locations are significant if we want to study gestation periods of scientific accomplishments, if we want to identify factors which contribute to scholarship. But since we are not pursuing these questions in detail, we have decided to focus on just one criterion: the place of appointment at the time when the prize was awarded. It appears that this criterion is significant because it identifies and singles out institutions as chosen by the laureates themselves.

The US dominance with regard to Nobel prizes parallels the one regarding publications and citations.

Further studies shall be necessary to shed light on the processes of research productivity, of course. Our cursory observations when we studied the biographies of laureates indicate that researchers of the caliber under discussion — the laureates themselves and occupants of what ZUCKERMAN (in reference to the French Academy) calls the "forty-first" chair — are highly mobile (for various reasons), they very consciously select their places of study or work, and they migrate towards elite institutions (and particular mentors there). Hence, a list of institutions of Nobelists, or other laureates, is nothing else than a set of institutions selected by the future laureates themselves. When we observe that many US Nobelists or Fields medalists were born and raised abroad, we can react in different ways: we can see that it was apparently possible to gain an excellent training in places like Auckland (New Zealand) or in Gelsenkirchen and Münster; but we can also observe what in Europe, in an alarming voice, has been called the 'brain drain', the migration of scientific talent from this side of the Atlantic to the other.

Nobel Prize With this introduction we may have a look at research institutions and their Nobel laureates (see Tables D.15 through D.22)[12]. If we count the number of laureates and group them by the location of the institutions (at the time the Nobel award was received), we arrive at a distribution shown in Table 6.4. From this table we can see that the general US dominance as far as Nobel prizes are concerned parallels the one we had shown in the case of publications and citations. In the field of chemistry, to be sure, where

[12] The tables are based on information found at the following site: `www.nobel.se`.

Table 6.5: NUMBER OF NOBELISTS PER INSTITUTION INVOLVED, by fields (Chemistry, Physics, and Physiology or Medicine [1945-2001], Economics [1969-2001]) and region (US vs. Rest of World).

	Region:	
FIELDS:	US	Rest
Chemistry	1.7	1.3
Physics	2.7	1.6
Physiology or Medicine	2.0	1.7
Economics	2.6	1.6

Europe has a long tradition and a strong industrial base, we observe no dominance of the US, particularly because scholars and institutions in two countries (in Germany and the UK) were very successful in attracting such awards. But in the remaining three fields (physics, physiology or medicine, and economics) the dominance is pronounced, considering the fact that we compare here US institutions against those of the rest of the world (i.e. in Europe, Japan, Australasia, etc.).

More non-US mathematicians were recipients of Fields medals than mathematicians working in the US.

In physics, we count roughly one third more laureates in the US than in Europe, despite CERN's location in Geneva; in physiology or medicine, we observe a similar distribution; and in the field of economics we are confronted with a clear domination of US science: when they received their prize, 60 percent of all laureates were associated with institutions within the US. But if we compare European with US institutions, we also observe that US science is more concentrated. Relatively fewer institutions are involved — in the fields of chemistry or physics, US institutions receiving Nobel prizes were even in the minority — and, hence, the average number of Nobelists per institution is higher in the US than in Europe (see Table 6.5)[13]. This is in line with the general observation that higher education in the US is highly diversified and research is concentrated in a narrow segment of institutions (see, in particular, section 8.2)[14].

Kyoto Prize and Fields Medal We have stated above that we shall look at three prominent science achievement awards: the Nobel prize just discussed, and the Kyoto prize as well as the Fields medal. As in the case of the Nobel prize where we concentrated on four fields (and did not consider the prizes in the fields of literature and contributions to peace), we shall look at two of the three fields in which a Kyoto prize had been established: 'advanced technology' on the one hand and 'basic sciences' on the other (without considering the third prize covering the 'creative arts and moral sciences').

[13] Only institutions with laureates were counted here, of course.

[14] To amplify this statement: In the year 2000, 83% of all federal research-and-development expenditures were distributed to just 100 institutions — or to about 2.5% of all institutions which form the US higher education sector [165].

If we look at the laureates of the Kyoto prize in the two fields under consideration (see Table D.23), we see that 22 had been conveyed to US scholars, and 17 to scholars located elsewhere (39 in total). We also see that more Kyoto prizes were given to honor developments in technological fields than in the basic sciences: 22 (or 56%) versus 17 (or 44%). 14 of the 22 US prizes (or 64%) were honoring developments in technology; in the rest-of-the-world group the corresponding share was 8 of 17 prizes (or 47%). 8 of the 22 US prizes (or 36%) honored basic scientific insights and the corresponding share among scientists working elsewhere was 9 out of 17 (or 53%). Hence, US scientists garnered a larger overall share of Kyoto prizes than those located elsewhere, and the prizes they collected were over-proportionally honoring 'advanced technologies' (as opposed to 'basic sciences'). In contrast, non-US scientists received slightly more prizes (9 of 17, or 53%) in fields of the basic sciences than their US peers.

The Fields medal, often referred to as the Nobel prize in mathematics, is the last prize we shall look into. Here we see — for the first time — a different distribution (see Table D.24): more non-US mathematicians were recipients of Fields medals than mathematicians working in the US (23 versus 17). Three nations with a long tradition in mathematics contributed significantly to this result: France, the UK, and Russia — or the former Soviet Union (see also Chapter 7).

6.2.2 Prizes and Honors: MIT versus ETHZ

On the backdrop of these general observations we shall summarize the collection of prizes by the two institutions concerned. If we look at the Nobel prize, Table 6.6 gives an overview on the prizes garnered by MIT, in the four fields under consideration and since 1945[15]. The statistics lists 52 laureates by function: faculty, staff and alumni, and in that preference ordering: the statistics does not include double counting, e.g. alumni as faculty members were counted as faculty only[16]. With such a statistics, MIT has an excellent record as far as Nobel laureates are concerned, not only regarding faculty or staff members, but also regarding former students, i.e. alumni (that is Nobelists at other instititutions).

Looking at the corresponding statistics of ETHZ (see Table 6.7), we see that the number of laureates under the ETHZ label are far less numerous[17]. The picture might be bettered a bit if we include among the faculty of ETHZ two laureates which fall outside the rules of our counting: Leopold S. Rusicka (Nobel Prize in Chemistry 1939), and Jean-Marie Lehn, visiting professor at ETHZ (Nobel Prize in Chemistry 1987).

Turning to the Kyoto Prize, we notice that among the 34 prizes issued between 1985 and 2001 (in two fields) we find eight individuals associated with MIT and two with ETHZ. Among the eight MIT individuals honored, there are five alumni and six faculty (three individuals qualify as both alumni

[15]In addition, a former alumni, Kofi Annan, and a retired staff member, Eric S. Chivian, shared a Nobel Peace Prize in 2001 and 1985, respectively.

[16]Two alumni of MIT, not counted in the statistics of Table 6.6, David Baltimore and Robert C. Merton, are faculty.

[17]Despite the fact that we counted in Table 6.7 Wolfgang Pauli (Nobel Prize in Physics 1945) among the faculty of ETHZ and not of Princeton (as in the Table D.18).

Table 6.6: NUMBER OF NOBELISTS OF MIT, by fields (Chemistry, Physics, and Physiology or Medicine [1945-2001], Economics [1969-2001]); based on MIT News (October 2001), `http://web.mit.edu/newsoffice/nr/-nobels.html`.

	MIT:			
FIELDS:	Faculty	Staff	Alumni	Total
Chemistry	2	3	5	10
Physics	7	8	9	24
Physiology or Medicine	5	1	1	7
Economics	7	—	4	11
Total MIT:	21	12	19	52

Table 6.7: NUMBER OF NOBELISTS OF ETHZ, by fields (Chemistry, Physics, and Physiology or Medicine [1945-2001], Economics [1969-2001]); based on `www.nobel.se`.

	ETHZ:			
FIELDS:	Faculty	Staff	Alumni	Total
Chemistry	3	—	—	3
Physics	1	1	3	5
Physiology or Medicine	—	1	1	2
Economics	—	—	—	—
Total ETHZ:	4	2	4	10

and faculty). The two individuals honored of ETHZ are faculty members; one of the two, Rudolf E. Kalman (Kyoto Prize 1985), is an alumni of MIT.

Lastly, a remark about the Fields Medal awarded after World War II. In that case, two medalists had an association with MIT: Daniel G. Quillen (Fields medal 1978) as faculty member, and Paul S. Cohen (Fields medal 1966) as staff member; no individual associated with ETHZ received the Fields medal.

6.3 Degrees

In institutions of higher education, and in particular in the context of performance-based budgeting, degrees are considered important output-indicators. We have already voiced our reservations regarding this position (see Chapter 2), not because we think degrees are unimportant, but because we think that educational performance may have to be measured by a whole array of indicators (the number of degrees being one of these). In the present chapter, we concentrated on research performance as indicators of institutional — and educational — achievement. To conclude this chapter, we shall briefly focus on degrees (and associated indicators).

MIT and ETHZ: Doctoral Degrees If we look at degrees (of any kind), two associated indicators play a role: time-to-degree, and completion rates. Both of these indicators are normally classified as process indicators. Completion rates of first degrees and time-to-degree will be covered in Chapter 4 (section 4.1.3). In the context of research universities and in the context of an associated output assessment, doctoral degrees play a role. Here, we can summarize the situation — and the relative standing of the two institutions — as follows:

- With 460 doctoral degrees awarded in the year 2000, MIT belongs to the top 20 doctorate-granting institutions of the US [104] (Rank 17, p. 33; see also our own calculations in Table B.4 which refer to 475 doctoral degrees). In engineering (with 198 doctorates), MIT holds the top rank, and in physical sciences (including mathematics and computer sciences, with 130 doctorates) rank two (behind the University of California at Berkeley). In Engineering and Physical Sciences combined, MIT has rank one.
- In contrast, ETHZ conferred a yearly average of 497 doctorate degrees (over the period 1998-2000, see Table C.4), a performance which would place ETHZ among the top 15 US research universities[18]:
  - In engineering (with 145 doctorates) ETHZ would fall roughly into the top five ranks[19];
  - in engineering and the physical sciences combined, ETHZ (with at least 315 doctorates) would be placed in rank two, just after MIT[20];
  - and in the physical and life sciences combined ETHZ (with 337 doctorates) would be placed in rank one[21].

Hence, if we take doctoral degrees as a significant output measure, MIT and ETHZ must indeed be counted among the world's leading research universities. ETHZ's performance in this respect might be surprising after our assessment of the bibliometric indicators of the two institutions. How does one assess the merit of a degree? Are doctoral degrees of MIT and ETHZ comparable? Are (doctoral) degrees of any institution comparable? Are degrees conferred by the same institution comparable? We have clearly more questions than answers. Many more detailed studies would be necessary to answer these questions.

[18]We have to keep in mind that universities with a better rank cover a wide spectrum of fields, from the natural sciences to the social sciences to the humanities to medicine.

[19]In the statistics of [104], computer sciences are counted as physical sciences, whereas at ETHZ they are listed as field of engineering.

[20]The physical sciences include physics and astronomy; chemistry; earth, atmospheric and marine sciences; mathematics; and computer sciences.

[21]The life sciences include biological sciences, health sciences, and agricultural sciences.

Chapter 7

Productivity Issues

Standing still is falling back […] The true university, however old, must draw together and reinvent itself every day.

Gerhard Casper [31]

In the preceding three chapters we focused — in analogy to a production process — on the input-output model of the university and juxtaposed the two institutions, MIT and ETHZ, on the basis of selected indicators. In Chapter 6 we described output-indicators, in Chapter 5 input-indicators, and in Chapter 4 we focused on processes, "transforming input into output" (to use the language of industrial production). If we summarize our findings thus far, we may conclude the following:

- If we look at the output-indicators selected — i.e. if we look at publication or citation counts, or Nobel prizes —, we see that MIT scores better than ETHZ in most fields. Furthermore, MIT appears to have not only greater depth, the institution is also engaged in a broader spectrum of disciplines than ETHZ.

- Concerning input, we do not observe a domination by MIT. The two institutions are roughly of the same size, at least if we look at the academic sector alone; their overall resource base must be (roughly) comparable; their entering students appear to have similar academic abilities; and both institutions recruit their faculty and staff worldwide.

- If we look at processes, however, or at the overall organizational setup — and the morphology[1] — of the two institutions, we observe clear differences. If we look at the micro-organizational level, we see that MIT has smaller student-faculty and staff-faculty ratios than ETHZ. MIT has a different macro-organizational setup than ETHZ: it is more structured (in schools and departments) than ETHZ (which has departments only); MIT appears to support cross-disciplinary (and cross-

[1] We refer here to the term as used by Pierre Bourdieu; see [20].

departmental) work in easier ways; and it offers more academic choices and programs.

Based on these observations we shall pursue in this chapter the question to what extent output — or input-output, i.e. productivity — differentials are attributable to differences of what we have subsumed under the headings of processes or morphology. We shall not be able to answer the question we raise, nor shall we provide convincing evidence which would link the productivity of an institution to its morphology: much more research will be necessary to establish such connections. However, we are convinced that at least the connection between research productivity and the morphology of the organizational setup of research is plausible and that future research should be directed to pursue this question further.

7.1 A Thought-Experiment

Over the years, while we were pondering the connection between research productivity and morphology, we confronted a range of academics of various nationalities, ranks and institutional home bases with the following thought-experiment:

> "Suppose that you are in charge with the founding of what should turn out to be a major research institute, a leading competence center of the world. This center should focus on one of the newly emerging (natural or life) sciences and should be entrusted to move science forward and to generate a positive impact on related sciences or technologies. You have enough resources at your disposal to finance 100 research positions. You are given two options to pursue, a research center with (i) four faculty positions (and, hence, 4 times 25 research positions), an option characteristic for many such centers in Europe, or alternatively a center with (ii) 20 faculty positions (and, hence, 20 times 5 research positions), an option more characteristic of situations one finds in the US. Which of these two options would you pursue if you wanted to maximize overall productivity of the center?" [2]

The overwhelming majority of those interviewed, Europeans or Americans, said they would choose the second option. That option appeared clearly superior to the first. Americans would perceive the second option as the more 'natural', because they generally lacked the experience with the first. But the same option was preferred by the Europeans as well, despite their own predominant experience with the first option: somehow it was intuitively apparent that the collegial — and hierarchically flat — setup of a range of small research teams, each lead by an able faculty member, was showing more potential than a few — hierarchically structured — larger research groups.

When we delved deeper to discern the reasons for their common preference, we collated a number of arguments in favor of the second option:

[2] The critical reader might argue that the two options could not cost the same: the first option would not consume as much resources as the second, because fewer — more expensive — faculty positions where involved. We say that the options are not that dissimilar. The second option would lack senior staff positions — *Oberassistenten, Privatdozenten*, et cetera — which cost about the same as an Assistant Professor position. And if this does not suffice to equalize costs of the two options, we may reduce the number of research teams in the second option by one or two.

- Faculty members could clearly devote themselves much better to their research: they have a small — and presumably dedicated — research group to lead, composed of doctoral and post-doctoral students. The social distance between faculty member and associated students would be small and the relation among the members of these teams could be one of mutual respect.
- Because of the relative smallness of the individual teams of the second option, 'horizontal' activities would by necessity take place. In contrast to the large research teams of the first option, where most necessary research activity would take place within these extended teams, teams of the second option would have to work in a 'horizontal' fashion with neighboring teams in order to gain access to know-how unavailable within the boundaries of their own group. Depending on the research pursued, team membership may have to change — or individuals (faculty as well as students) would be members of several teams.
- Faculty had a range of colleagues 'next door' with whom they could engage in scientific discourse or in scientific collaborations: colleagues would be not only people with whom one would protect the common interests of the faculty position (i.e. the *Standesinteressen).* Faculty had the option to talk 'horizontally' to organizationally independent people, not only 'top-down' to individuals in a dependency position. Because of the setup of the second option, a broader spectrum of know-how could be covered, but there would also be a inherent 'redundancy', a certain overlap in know-how within the entire center, which would ease mutual representation (in various contexts such as teaching, research, administration, et cetera).
- Lastly, the second option would allow to distribute teaching loads and the administrative burdens of faculty members — i.e. those associated with research management and the membership in standing or ad-hoc committees of one's institution — onto more shoulders.

Not all who were asked to respond to this scheme would see it in favorable terms. One European senior faculty member who had just returned from a sabbatical at the California Institute of Technology, known for its excellent research and exemplary student-faculty and staff-faculty ratios, responded that he was happy to be back in his larger research group: he wouldn't want to hold a faculty position there. In fact, if given the option, many European faculty members in engineering, the sciences, or in the medical fields would opt or fight for larger staff groups.

It is clear that from the perspective of individual faculty members, to be in charge of a larger research group is attractive: in this way, they think they can maximize their own research output, their influence and prestige — and possibly also their income. If this attitude becomes the norm, even faculty members who would support a flatter organization will be forced to fight for larger research groups, or else their collegial standing would suffer. Furthermore, in such situations presidents and rectors of universities find themselves under pressure to offer 'favorable' conditions to possible candidates of a senior faculty position, or else they loose out to research organizations — such as the Max Planck Institutes — which might offer their candidates 30 staff positions (or more). In this context, we shall have to distinguish between two vantage points:

- the position of the individual faculty member, just described; and
- the position of senior administrators at an institutions (i.e. presidents, rectors or deans).

It is natural — and legitimate — that faculty members fight for their own positions, and we can understand that some faculty will want to work with large research groups. But as senior administrators, our vantage point should be a different one: not to maximize the research output issued in the name of individual faculty members, but to maximize the research output for the institution in their entirety.

We believe that the observed productivity differentials between MIT and ETHZ — and between US and European universities in general — are tied to an unfavorable morphology of European institutions.

And here the productivity question is being posed: if we pursue a policy to appoint (fewer) faculty with the understanding to provide a larger number of research staff positions, will we then foster excellence of the institution and research productivity as much as when we pursue a different policy whereby we will appoint (more) faculty, but supply them with fewer staff positions? Inconclusive evidence (presented in previous chapters) and some historical analyses (presented in Chapter 8) indicate that this is unlikely the case[3]. We tend to believe that the observed productivity differentials between MIT and ETHZ — and between the research universities of the US and Europe in general — are tied to an unfavorable morphology of the research institutions we find in continental Europe.

7.2 Empirical Evidence

The link between research productivity and institutional morphology is poorly researched, unfortunately, and additional studies shall be necessary to shed more light onto a relation we intuitively feel as being valid. Although we can easily presume substantial output — or performance — differentials between nations and institutions, a closer study of these differentials is relatively rare [164] and may only in recent times have become more prominent [53, 33, 35]. If we look across the Atlantic, we observe differentials in performance and morphology (see Chapters 6 and 4). But we have yet to show, in the course of further studies, that performance differentials are

[3]If the first option setup were associated with maximizing overall research output of an institution, marginal productivity of an average researcher (faculty or staff) would be higher in this setup than in the one of the second option. All evidence we have points to the fact that this is not the case.

attributable — or partially attributable — to differentials in the morphology of institutions: other factors may be more prominently involved.

Group Productivity Some studies exist which deny any relation between research productivity of teams and the size of these teams (i.e. morphology). JOEL E. COHEN claims that

> "[…] the average output of a scientific or technical research group is directly proportional to its size […] Hence, groups of different sizes have the same average output per unit of size. There is no reliable evidence for the existence of a size or a range of sizes for a research group that maximizes output per unit of size." [46],

In an earlier paper he states that "the total number of […] of publications per research group per year [is] approximately proportional to the number of […] individuals in that group" [44]. This position may be seen as a response to other positions which postulate an economics of scale effect, i.e. that per capita productivity increases with the size of the group [45]: "A plotting of relevant publication rate per person against successive ranges of group sizes yields graphs with an initial linear rise in per capita publication, followed by several maxima at various group sizes, suggesting that optimum efficiency occurs at specific sizes" [181]. But other studies come to the originally cited conclusion: "there is strong indication of a linear relationship between R&D expenditures and number of papers" [150]. A more moderate position is taken by a group of authors which had studied over 200 research teams in the US to focus on the social structure of R&D teams: "Results show that scientific productivity is context and situation dependent" [202].

Not all studies of this era deny the relation between the research productivity and the size of the corresponding research teams. The psychologist FRANK M. ANDREWS, in summarizing the results of a classic — and detailed — study on "Scientists in Organizations" [177] and the "productive climates for research and development", lists factors which contribute to innovation and scientific output (p. 346):

> "[…] creative ability tended to pay off more […] in the following kinds of settings: (i) when the scientist perceived himself as responsible for initiating new activities; (ii) when the scientist had substantial power and influence in decision-making; (iii) when the scientist felt rather secure and comfortable in his professional role; (iv) when his administrative superior 'stayed out of the way'; (v) when the project was relatively small with respect to to number of professionals involved, budget, and duration; (vi) when the scientist engaged in other activities (teaching, administration, and/or other research) in addition to his work on the specified project; and (vii) when the scientist's motivation level was relatively high."

Most of these factors can be linked to the morphological setting of the work environment which we addressed when we were initially discussing our thought-experiment: apart from individual factors, it is the organizational setup which implicitly empowers — or impedes — people to contribute.

We have stated before that output differentials are evident in a cross-cultural context characterized by substantial morphological differences. We have also stated that the causal link between morphology on the one hand

and productivity on the other has yet to be established. Studies are needed which substantiate this relationship in an intra-cultural context. All of the studies cited above used this particular context to address their research question, but their results were — at least from our point of view — inconclusive. If we study a particular culture of higher education institutions, we should be in a position to exclude cross-cultural factors which might 'contaminate' our sample and we can focus on differences within such a population. But here we are confronted with two contra-rotating tendencies which might cancel each other in regression analyses: the tendency that increasing quality and reputation is associated with higher research income and, hence, a larger staff; and the hypothesis that larger teams are subject to diseconomies (as the size of the team increases beyond an optimum).

7.3 Change Management

But let us assume now that senior university administrators are favorably disposed towards our notion that the productivity — or effectiveness — of institutions could be increased through an appropriate adaptation of the institutional morphology. How should one go about to affect this change? What are the co-requisites we shall have to pay attention to?

> *Measures which are designed to change longstanding practises will need years, perhaps decades to become effective.*

It should be clear at the outset that measures which are designed to change longstanding practices will need years, perhaps decades to become effective. It should also be clear that measures which affect vital interests of faculty and staff will have to work on two fronts: they will have to slowly change the culture so characteristic of our universities, and they should gradually phase out faculty and staff which do not fit the newer concepts[4]. That the cultures of universities and the motivations of faculty and staff might differ may be illustrated by anecdotal evidence. A former professor of Harvard University and current rector of a European institution expressed his dismay thus: "Everybody wants to work at Harvard, even if one will have to work in the kitchen".

Change management [100] is not the topic of this study, but we should point out major foci of change if we would want to transform institutions and affect favorably their morphology. Strategies of change will have to depend on an assessment of the *status quo*. We may picture the *status quo* of institutions in function of two indicators characteristic of organizational matters and resource availability: student-faculty and staff-faculty ratios. On the basis of these indicators we shall be able to sketch a 2×2-table which will allow us to classify research universities (see Table 7.1). The resulting four classes of institutions can be regarded as 'ideal-types' of institutions (Types 1 through 4). If we adhere to the notion that low student-faculty and low staff-faculty ratios are positively related to research productivity (Type 1), and if we would want to increase research productivity, our task

[4]Through the natural process of retirement.

would become one of transformation, from institutional Types 2, 3 or 4 to an institution of Type 1.

The Situation in Germany Let us first look at the situation as it presents itself in Germany. There we observe two parallel strategies for research institutes on the one hand (Type 2) and for universities on the other (Type 3). As we shall show in Chapter 8, the placement of the German university as a Type 3 institution can be traced to historic roots, to its concept of the *Lehrstuhl* and the prevalent notion of the teaching-learning nexus. The Type 3 institution is characterized by high student-faculty ratios (see section 4.1.1) and by low staff-faculty ratios (see section 4.1.2): the high student-faculty ratios are a byproduct of the Humboltian tradition while the low staff-faculty ratios are a result of retrenchment. According to the ideal-type of the Humboldtian notion of the *Lehrstuhl*, a faculty member assumes responsibilities for a field and — consequently — lacks direct academic colleagues within his or her own faculty: whatever takes place within a field at an institution takes place within the corresponding *Lehrstuhl*. The implicit matching of *Lehrstuhl* and field of investigation (research and teaching) impedes the development of subfields as well as that of a collegial culture. As a consequence, the Humboldtian university doesn't cover as many fields or subfields as a corresponding US institution; it has smaller departments or faculties, knowledge transfer and lecture courses play a dominant role, and the intimate face-to-face contact of student and faculty takes place during later portions of a degree program — if at all[5].

The implicit matching of the 'Lehrstuhl' and the field of investigation impedes the development of subfields as well as that of a collegial culture.

With the onset of mass higher education, the ideal-type of the Humboldtian *Lehrstuhl* may have been watered down and more faculty positions had to be formed, but the ideal-type itself — or its particular interpretation — was seldom critically evaluated. Because of the increased teaching burden that came about with mass higher education, research was impeded (by a lack of resources and an implicit dilemma between teaching and research) and a parallel institutional type became increasingly prominent: that of the dedicated research institutes (Type 2 institution). The dedicated research institutes were instrumental in alleviating the deficits in the research fields which developed in the course of a restricted funding of higher education institutions: large proportions of government funds earmarked for research, roughly 40% of the total, flow into institutes such as these. In Type 3 institutions, staff-faculty ratios are, in line with the Humboldtian ideal-type, high. At the same time, student-faculty ratios are low — or lower than in the corresponding university setting — because the in-

[5]The normal view of the German system and the lamentations about its performance trace its dismal state not primarily to any shortcomings of the system but to factors such as "budget-slashing and hiring freezes" or "postreunification cuts": the universities are seen, perhaps rightly so, as "underfunded and overcrowded" [114]. But there are other views as well. Patricia Kahn cites Jürgen Rüttgers, then Germany's science and education minister, in his defense of retrenchment as a way to refocus an inefficient system which "has not had the courage to start its own reforms".

stitution caters to doctoral students only. An institute of that type is run by few professors with a relatively large research staff. Because the institutes are well funded, output is relatively high. But doubts have cropped up concerning the cost-effectiveness of Type 3 institutions: "Of the [Max Planck Society's] 2,800 scientists below director level, only 30 are officially independent group leaders with their own resources" [113]. PATRICIA KAHN cites WALTER HILL, a University of Montana scientist and advisor of the Max Planck Institute for Molecular Genetics in Berlin: "It throws a blanket over other people [... and] encourages them to become puppets of the director" (p. 570).

Portions of what is called the 'Mittelbau' (other than doctoral and post-doctoral students) appears obsolete. Members of the 'Mittelbau', if qualified, should be put in a position to pursue a tenure track — or leave the university altogether.

If we summarize the German situation, we see that two institutional types (i.e. Types 2 and 3) are entrusted with the task to further science education and research. The two types complement one another, but they appear to be no proper substitute for Type 1 institutions. Research was concentrated in special institutes (of Type 2) because of fears that an even spreading of resources within universities would dilute research and would, hence, not produce outstanding results. Because the German concept of the university prevented a diversified higher education system [86, 216], research funding had to be concentrated in special institutes when universities were increasingly under-funded in the wake of mass higher education.

Since the German research institutes are firmly established, one might ponder what role they may play in the course of reforming tertiary education and research. Research institutes (of Type 2) have ample space for improving their effectiveness: they could flatten their organizational structures and internally redistribute their resources in support of more 'empowered' but smaller research groups — and thus tune their faculty-staff ratios. In this way, research institutes could better assume the tasks of graduate education. But if Type 2 institutions were to form a model for graduate education, Type 3 institutions are deficient in their function to foster undergraduate education and to serve as feeder institutions for research institutes[6]. Hence, special alliances and programs would be needed to improve the bonds between research institutes and associated universities — in order to improve undergraduate education and to recruit prospective doctoral students earlier.

The Situation in Switzerland If we look now at the situation we find in Switzerland, we see that in certain fields — such as the natural sciences and engineering — institutions or specific disciplinary sectors (i.e. *Fachbereiche* or *Fakultäten*) are of Type 4: in line with a certain adherence to the Humboldtian doctrine and in line with a comparatively (still) decent resource

[6]We shall not dwell on the definition of undergraduate and graduate education which will depend on the context under discussion.

base, their staff-faculty ratios and their student-faculty ratios are high. We have seen (in Chapter 6) that these institutions are dominated by US institutions (of Type 1) as far as research output is concerned and we speculated at the outset of the present chapter whether there is a link between research output and the morphology of the institutional setting in which research is produced. If this relation between research output and institutional morphology appears reasonable, the Swiss institution — and in particular the ETHZ — is in a unique position to institute reforms from within: no outside resources would be necessary and simple, internal re-distributions of resources would suffice to enhance significantly faculty-staff — and by implication — student-faculty ratios (and to transform Type 4 into Type 1 institutions)[7].

Table 7.1: Classification Scheme of Leading Research Universities and Research Institutes (or *Fachbereiche, Fakultäten*).

		Staff-Faculty Ratio	
		low	high
Student-Faculty Ratio	low	Type 1: US Institutions of Higher Eduation (MIT etc.)	Type 2: Research Institutes (Max Planck Gesellschaft etc.)
	high	Type 3: German Universities (RWTH etc.)	Type 4: Swiss Universities or *Fachbereiche, Fakultäten* (ETHZ etc.)

[7]With an internal re-distribution of resources we mean primarily a substitution of staff members (other than doctoral and post-doctoral students) by faculty. This particular staff category, i.e. portions of what is called the *Mittelbau*, appears obsolete in most cases. Members of the *Mittelbau*, if qualified, should be put in a position to pursue a tenure track or leave the university altogether.

Chapter 8

Institutions within a Context

Effective leadership […] starts with powerful questions.

Richard Chait [36]

In the preceding Chapters 3 through 6 we were basically reporting data, data selected from a particular point of view, of course. Around this core of 'facts', so to speak, we presented in Chapter 7 a first shell of interpretation, a collection of 'hunches' regarding basic questions of productivity as they refer to organizational matters within an institution and as they pertain to the environment of a research university. In the present chapter, we shall add a second layer of interpretation in that we look at cultural factors which might guide an institution: factors which are cherished by the respective academic communities, which are overtly followed as guiding principles, or covertly complied with because of a lack of reflection or insight. We have alluded to before that we are not only looking at two institutions as such, but at two cultures of higher education, and that we would like to shed light on the interplay between the form of institutional governance or management and the cultural and societal context within which an institution is embedded; hence also the subtitle of this Report.

8.1 Changing Environment

Increasing Student Populations A good point to start with our sketch of the culture of higher education is the present status of mass education. As we study the history, sociology and philosophy of higher education, we are likely studying an elite phenomenon: before World War II, the university community was small, and it perceived itself primarily as a cultural elite [73, 238, 234, 74], despite a few authors — like MAX SCHELER [189] — who already foresaw and discussed basic elements of mass higher education systems. Before World War II, student participation rates in European universities did normally not exceed 5–6% of the corresponding age groups, while participation rates in the US tertiary education system (i.e. including non-university level institutions) before the introduction of the so called GI-Bill (1944) were around 9% [43] (p. 31). The small student participation rates in the respective university systems were perhaps indicative of a comparatively homogeneous student body, at least as far as cognitive abilities or scientific and professional aspirations were concerned[1].

After World War II, participation rates in tertiary — and university — education systems grew. This growth phenomenon has a number of causes which we have no time, nor reason, to trace in detail; but we shall allude to some [43] (see e.g. p. 24 and Chapters 3 and 7 in that book). The restructuring of the respective economies and the corresponding rebuilding of society and growth of industry (secondary sector of the economy), following World War II, demanded an educated and professional work force. Income prospects increased generally, giving rise to a consumer economy; and income prospects increased in function with education[2]. In the US, the "inclusion of educational entitlements among the benefits for veterans in the GI-Bill" had quite significant effects as far as participation rates in higher education were concerned [77] (pp. 70–74)[3]. In the 1950s, the Cold War and the Korean conflict fueled the US economy — and indirectly also these of other Western nations — and with the launch of Sputnik in 1957 and the corresponding culture shock an expansion of the US higher systems was initiated and a period came into view (1945–70) which, in retrospect, we now see as "Academia's Golden Age" [77][4].

In the year 1970 MARTIN TROW published an article in which he postulated that the character of higher education significantly changes if participation rates exceed 15% and that further major changes could be expected if participation rates approached 50% [220]. In fact, US participation rates in tertiary education exceeded the first of TROW's threshold already 20 years earlier [43] (p. 31); but if we exclude propaedeutic or pre-professional institutions (2-year-colleges), roughly a third of the total of all higher education institutions around 1970, TROW's claim is more timely. In Germany, for instance, the 15% participation threshold (at the university level) must have been passed around 1975; between 1960 and 1990, the rate of entering students (in the territories of the old *Bundesrepublik*) more than tripled and the number of total students at the university level increased five-fold [29] (pp. 140). Today, we have overall participation rates which cover a spectrum between roughly 20% (Switzerland), 30% (Austria, Germany, Netherlands), and 40% (UK and US) [170] (pp. 174–176)[5].

[1] That is not to claim that the university of the past was uniformly homogeneous. For instance, the historical European university was far more international than the corresponding institution of today. See e.g. [96].

[2] This period in Germany, for instance, was known under the name of *Wirtschaftswunder*.

[3] "For most of 1946, MIT received four thousand applications per month — an example of a common pattern. Between 1945 and 1950, about 2,200,000 former servicemen enrolled in college through the GI Bill, more than three times the maximum figure projected during the war. Sixty thousand former soldiers applied to Harvard alone. Educators responded with the spirit of patriotism — and gratitude — characteristic of the postwar years." [77] (p. 74).

[4] Ph.D-studies, for instance, grew eventually by annual rates which exceeded 10%. Between 1962 and 1971, the number of doctorates awarded exceeded 10% in eight years (the range was 8.0% in 1971 and 14.6% in 1970), leveling off after 1971. See [104], p. 31.

[5] These figures are a bit misleading, from a Swiss point of view, because of OECD's definition of the university sector. In the UK, the binary (or dual) system of higher education was abandoned to form a unitary system, in that the former polytechnics where integrated into the university sector; in the US, a wide spectrum of colleges are apparently counted as universities; in Austria we are confronted with a problem of *Scheinimmatrikulationen* which

Shrinking Resource Base With the expansion of higher education in the second half of the 20th century most tertiary systems were confronted with problems to finance their systems at the accustomed levels. The financial problem is readily apparent: if (real) unit costs remain stable, total costs will increase with the expansion of the system. Ever higher proportions of national or personal income must be spent to sustain established levels of education and research — in competition with other worthy causes, such as social security, health, environmental protection, transportation, etc. Because higher education is labor intensive, unit costs actually are not stable: they increase (relative to other factor costs). Furthermore, the industry-proven ways to reduce unit costs by a substitution of capital for labor is difficult to accomplish [147][6].

As a consequence, tuition and fees in the US increased faster than price indices [25, 95], some systems were unable to retain their earlier (per caput) resource levels while others had to fight retrenchment. As the president of the University of Minnesota, MARK YUDOF, says [243]:

> "[…] over the past 25 years, [the] agreement [between state government and public research university] has withered, leaving public research institutions in a purgatory of insufficient resources and declining competitiveness."

And further:

> "While higher education's share of average state spending fell 14 percent from 1986 to 1996, Medicaid's share nearly doubled. The funds allocated to correctional facilities grew by more than 25 percent."

The situation US research universities found themselves in the latter part of the 20th century was accentuated by the end of the Cold War by corresponding redefinitions of the budget of the Department of Defense (DOD) [163], and by a general tendency among larger industries to reduce or close their in-house research groups[7]. If we look at the case of Germany, we saw that student numbers had increased five-fold between 1960 and 1990, but personnel increased only by a factor of 3.8 [29] (p. 218).

With the expansion of higher education most tertiary systems were confronted with financial problems.

While we respect the complaints of MARK YUDOF, of course, we should take recognition of the fact that the relative position of the US is still not that bad: R&D-expenditures (as a percentage of GDP) are topped by only a few countries (Sweden and Japan — see Table A.2), and a similar picture can be constructed when we look at educational expenditures in general where US expenditure levels are exceeded only by Sweden and Switzerland (see Table A.1). We should also note, once again, that figures pertaining to averages of large populations have their limitations: R&D-expenditures in selected US-states are significantly higher than

appear to inflate the corresponding figures by 40% [176]; etc.

[6]The other option pursued by industry, namely to relocate production sites to developing countries with cheap labor, is equally infeasible.

[7]This tendency might be due to the spreading of the profit-center approach to management. Research groups within many industries worldwide were closed or thinned out, and basic research — i.e. research with a longer gestation period — was more or less delegated to universities.

the US average (see Table A.3) — and significantly higher still than the corresponding expenditures in other nations. Hence, while the situation in the US may have worsened since the days of the Golden Age of academia, other nations find themselves in a far more precarious position.

Adaptation Processes In light of these developments, higher education systems had to adapt to this changing environment. Adaptation occurred earlier, and in subtler ways, where institutions were more subject to 'market' forces. In the US, for instance, this adaptation had a long history, dating back at least to the foundation of the American research university in the middle of the 19th century. While US institutions compete nationally — and inter-nationally — for students, faculty, funds and prestige, European institutions generally have a far more limited reach. International research cooperations of European institutions and some internationally composed leading European institutes belie the fact that the European university is a far more local institution than its US peers [233] [8] [9].

Adaptation occurred earlier, and in subtler ways, where institutions were more subject to 'market' forces.

What were the chosen forms of adaptation during the past quarter of a century, and what are the prospects now? What were the opportunities missed? Back in the early 80s, when Zürich was troubled by riots which became known as the *Opernhaus-Kravalle*, a journalists reporting in one of the magazines like 'Newsweek' or 'Times' coined the expression of the 'Helvetic-Retardation-Effect'. He argued — tongue-in-cheek — that Switzerland belatedly went through times which other nations experienced around 1968. This is a frequently expressed sentiment, namely to see Switzerland as a nation retarded not in her technological, but in her social development. Whether this makes sense or not is not that relevant. Important is perhaps the observation that social developments have different origins and differing potentials to spread. And there are advantages not to be in the vanguard of all mainstream currents. Instead of steering by having to look into the rear view mirror of history — or instead of not steering at all —, we may see possible futures right before our very eyes. But the advantages vanish if we do not use this vital information to guide us in our selection of the paths to be pursued [99].

Hence our insistence to observe and monitor the larger, international

[8] Curiously enough, this has not always been the case. The leading European universities of the 19th and the beginning of the 20th century were very international in orientation, perhaps because of a unifying force of the German language, since lost, which stretched far into Eastern Europe; perhaps also because of political factors or ethnic persecutions in various regions. Students followed teachers all over Europe and faculty members were mobile, linking Berlin with Vienna, Heidelberg with Prague, and Zürich with Budapest.

[9] Reasons for an early mobility among students and faculty raise a broad and important topic we do not want to cover here. One example, however, attesting to the fact of internationalization. We mentioned the compilation of *Matrikel* of the University of Zürich (1833–1914) before [96]. A glance at this list will reveal that the students from Switzerland were in the minority. Students came in sizable numbers from Russia or Poland, from Germany, Austria or Hungary, or from Great Britain or the USA, etc. Keep in mind that the area definitions of those days were different than those of today.

Table 8.1: US Distribution of Higher Education Institutions (Year 2000), Enrollment in Institutions of Higher Education (Fall 1998), and Research Expenditures (Fiscal Year 1998), by Carnegie Classification of Institutions, based on [204] (p. 20f and p. 29).

Category of Institutions	Institutions (%)	Enrollment (%)	Research (%)
Doctoral & Research Universities	6.6	28.1	89.4
Research I & II	3.8	20.7	80.5
Doctoral I & II	2.8	7.4	8.9
Master's Colleges & Universities	15.5	21.4	2.4
Baccalaureate Colleges	15.4	6.9	0.4
Associate's Colleges (two years)	42.3	40.1	—
Specialized Institutions & Tribal Colleges	20.1	3.5	7.9
Total	100.0	100.0	100.0

currents of higher education development: only thus can we attempt to understand and reflect upon the stances and development patterns of the two institutions under investigation. Within the time span of the past quarter century, we may distinguish five major responses of tertiary education to the general societal and economic development:

- the diversification of higher education, particularly in the US;
- the reform of governance and management of higher education systems and institution, both in the US and in Europe;
- attempts to build a European alliance (as part of what has now become known as the 'Bologna Process');
- a new focus on so called 'hybrid' institutions, combining features of public and private universities; and lastly
- attempts to fashion 'virtual' institutions.

8.2 Diversification of Higher Education

The North American Context In the US, the increase of student numbers and the widening access to higher education — due to the GI-Bill, the baby boom, the increasing participation rates of the relevant age cohorts, adult and further education, higher enrollment rates of foreign students, et cetera — brought about an increase in the number of higher education institutions. In the last 25 years, roughly 1,000 tertiary institutions were added for a total of 3,941 in the year 2000, the proportion of doctoral and research universities rose from around 6.0% in 1975 to 6.6% (see Table 8.1), and a total of slightly more than 15 million students were enrolled (Fall 1998).

As can be gathered from Table 8.1, roughly 28% of all students are enrolled in institutions conferring doctoral degrees, and if we look at research-oriented institutions alone, the ones we might consider as the 'peers' of European institutions, the share drops to roughly 21%; these institutions alone account for roughly 80% of the total amount of research expenditures at universities and colleges in the US. The remaining 70–80% of all students attend other types of institutions: Associate, Master's or Baccalaureate Colleges, catering to a wide variety of students, young and old, of varying socio-economic as well as ethnic backgrounds and differing native abilities and talents. Some of these Colleges — i.e. Colleges of Liberals Arts I and Baccalaureate I, 5.8% of the total and enrolling roughly 2.5% of the student population — are as selective as Research Universities I.

None of the US research universities are profit oriented.

In contrast to the European context, the share of private (non-profit) institutions in the US is sizable (see Table 8.2), and in recent years even for-profit institutions have expanded. In Europe it has become common to associate private institutions with teaching and research excellence, but this view appears a bit narrow. True enough, there are many excellent private institutions, but among the top 20 research universities rated "best balanced" in the US (of the year 1993) [118], we count 8 public institutions [164]. There is even a hunch that authors, proposing to found for-profit institutions in Europe as a vehicle to increase quality of education and research, misunderstand charter and mission of private (non-profit) institutions in the US[10]. We ought to keep in mind that none of the 151 Research Universities of the US are profit-oriented. The difference between public universities on the one hand and private (non-profit) institutions on the other is there, but the differences are not that pronounced. Both types of institutions are:

- funded by public sources; large amounts of federal research appropriations flow into private research universities (grants, scholarships, etc.);
- characterized by a diversified funding base (tuition and fees, federal research grants, endowment income, income from patents, land grants, etc.); and
- characterized by the "[…] four essential freedoms of a university — to determine for itself on academic grounds who may teach, what may be taught, how it shall be taught, and who may be admitted to study"[11].

Diversification Compared The difference between public and private research universities within the US is clearly far less pronounced than between

[10] Peter Glotz e.g. is one of the proponents of for-profit institutions — a strange position for a person who was once a spokesman of the German Social Democrats and an unusual stand for a scholar in the field of higher education (and media management): "[…] einige Bundesländer [von Deutschland sollten] den Mut haben, die eine oder andere Spitzenuniversität nach dem Vorbild von Telecom und Post zuerst zu privatisieren und mittelfristig an die Börse zu pringen. Drei (von hundert) Universitäten würden genügen, wobei allerdings renommierte Institute mit breitem Fächerspechtrum einschliesslich technischer Fakultäten ausgewählt werden müssten. Beispiele wären die Technische Universität München, die Humboldt Universität in Berlin oder die Rheinisch-Westfälische Technische Hochschule Aachen." [88, 131].

[11] US Supreme Court Justice Felix Frankfurter in the Sweezy vs. New Hampshire case, US 234 (1957).

Table 8.2: US DISTRIBUTION OF HIGHER EDUCATION INSTITUTIONS (YEAR 2000), by Carnegie Classification and by Control (Public Institutions, Private Not-For-Profit Institutions, and Private For-Profit Institutions), based on [204] (p. 6).

CATEGORY OF INSTITUTIONS	Public (%)	Private (%)	For-Profit (%)
Doctoral & Research Universities	4.2	2.4	0.1
Research I & II	2.6	1.2	—
Doctoral I & II	1.6	1.1	0.1
Master's Colleges & Universities	6.9	8.4	0.2
Baccalaureate Colleges	2.3	12.7	0.4
Associate's Colleges (two years)	26.0	4.0	12.3
Specialized Institutions & Tribal Colleges	2.3	15.2	2.7
Total	41.7	42.7	15.7

US and European universities. When we compare public US and European (continental) institutions, we see marked differences, despite recent efforts to modernize the European institution [28, 42]:

- government and management structures of institutions are still quite distinct (see Table 8.4);
- the European institution has a generally less diversified resource base;
- the (continental) European university generally lacks what has been termed (by US Supreme Court Justice FELIX FRANKFURTER) the "fourth essential [academic] freedom", namely to have control over admissions[12];
- some European university systems — such as the German — even lack other freedoms postulated by FELIX FRANKFURTER: the first (who may teach) and the second (what may be taught);[13] and
- among the US institutions are many with a continental — even global — reach: they reach out to potential students within the entire North-American continent and attract students in sizable numbers from all over the world; and they fashion their own diversified institutional profiles to be able to carve out their corresponding market shares in education and research.

Diversification appears to be a key element in efforts to modernize and reform higher education [221]. But the avenues pursued by European systems may not bring about the necessary stimulation and changes. BURTON

[12]This is hard to understand in view of the fact that European tertiary institutions other than universities practice admission management (e.g. *Fachhochschulen* in Switzerland). In the UK, the situation is clearly different. See in this regard the controversy which surrounded the so called 'Laura Spense affair' in the first half of the year 2000 [242].

[13]This may come to a surprise to some who are proponents of the Humboldtian system, but a reading of the new *Hochschulrahmengesetz* shows that this is indeed the case — see section 8.3, 'Foci of Current Reforms in Germany'. When the former president of Stanford University, GERHARD CASPER, was asked why Stanford was so successful, he answered that Stanford apparently implemented the Humboldtian ideals better than the German university.

R. CLARK, a keen observer of higher education in general and European systems in particular, remarks as follows [41] (p. 37f):

> "The creation of standardized and tightly controlled sets of institutions within a centrally planned binary or trinary system may offer very little long-term stimulation. The new scheme may simply create new sets of protected niches in which, under common categories of guaranteed funding, institutions find little incentive to be alert to a changing environment."

Furthermore,

> "Dynamic diversification requires system conditions that promote institutional autonomy to the point where individual institutions within an institutional complex, e.g., a set of research universities, can become very different from one another. The institution can then seek to develop distinctive profiles of activities, advantages matching their changing internal capabilities, e.g., departmental strengths, with changing environmental constraints and opportunities, e.g., governmental funding as share of total support from the European Union. We can call this increasingly needed state of affairs 'active diversification'."

Diversification, as alluded to in the present context, goes far beyond the creation (or abolition) of a stratified higher education system. We note that in the UK, for instance, the former binary (or dual) system had been abandoned (in that the polytechnic institutions were integrated into the university system), while Switzerland is in the process to create a second layer within tertiary education (through the formation of *Fachhochschulen*). We also note (see Tables 8.1 and 8.2) that the US system has in fact at least three layers. Diversification transcends the structures of higher education systems, be they unitary, binary or trinary. While layered systems pose their own problems and call for their own solutions, they do not directly affect diversity: diversity has more to do with how higher education systems are governed or managed.

Binary Systems A side remark may be admissible concerning the current discussion regarding the formation of *Fachhochschulen* in Switzerland. Despite the fact that this new layer of tertiary education institutions was formally formed, many problems remain unresolved:

- There does not exist a proper rationale regarding the mission of *Fachhochschulen* vs. that of universities. A topos states that basic sciences be pursued at the universities, whereas the applied sciences be fostered at the *Fachhochschulen* — in contradiction to the history of the university which catered, from the very beginning, to the professional (clerics, lawyers, medical doctors, engineers, architects — and nowadays business or computer professionals, et cetera).
- *Fachhochschulen* are specifically charged to conduct (applied) research, without being accredited to offer doctoral programs — and without, hence, having access to those primarily supporting research: doctoral and post-doctoral students (and if *Fachhochschulen* were accredited, generally, to confer doctorates, the specific layer would vanish)[14].

[14] This charge may also send a wrong message to funding agencies evaluating so called 'applied' research at universities and institutes of technology.

- Because of the specific decree that *Fachhochschulen* focus on applied subject matters, universities may be implicitly hindered in developing applied fields where there is a demand. There is no intrinsic reason, for instance, not to offer nursing or social work at the university level — or landscape architecture, for that matter — and, in so doing, diversify disciplines where there are too many graduates to be absorbed by the labor market[15].
- *Fachhochschulen* (in Switzerland) are currently being formed through the administrative merger of former technical colleges. These administrative mergers will not suffice to generate the necessary economies of scale nor will they secure the envisaged academic quality.

Admission Management We have mentioned what US Supreme Court Justice Felix Frankfurter called the "fourth essential [academic] freedom", namely to have control over admissions. The aim of admission management is twofold: to admit, in quantitative terms, a population of students which is not overtaxing the resources of the institution; and to admit, in qualitative terms, a population which fits the mission of the institution. There are various advantages to admission management:

- Institutions which practice admission management admit not a larger student population than they can handle.
- Because of this, the institution can employ didactic approaches which are focused on student learning from the very beginning. Exams, tests or projects are used as communication devices between teacher and student to monitor progress of learning and academic development — and not as devices to screen and exclude students from further study.
- Institutions which practice admission management have much higher retention rates than institutions with open access.

Admission management, if properly administered, selects students which are capable to pursue their chosen studies. Under this premise, insufficient course grades will normally not lead to the conclusion that students are incapable or not talented enough to pursue a particular line of study; rather, they might point to the fact that the teaching-learning mode ought to be improved — or that students might require help for problems not directly associated with their studies.

Conversely, institutions (of repute) which practice open access have entering classes which are frequently far too large [108]. In order to handle

[15] To our knowledge, just one program started recently at the university level (in Switzerland) in the fields of nursing (University of Basel) and there is only one in social work (University of Fribourg). The reluctance to offer these fields at the university level constituted a clear discrimination of women (who dominate these professions to this day), considering the fact that most engineering disciplines are offered at the level of universities as well as *Fachhochschulen*. To argue that these fields lack the research-content, the *Wissenschaftlichkeit*, is a very short-sighted argument: no discipline develops a proper research base without being rooted in a university environment (nursing is covered by ISI under the name of "health care sciences and services"). In all these cases it will be argued that the fields under consideration lack *Wissenschaftlichkeit*, in spite of the fact that US elite universities offer programs in these fields.

such student populations, outmoded teaching approaches are being used with a focus on lecture modes, knowledge transfer, passive learning, and exam systems which test frequently lexicographic knowledge. The first one or two propaedeutic years at the university are used to thin out the student population to a manageable size. Such approaches are applied even in fields where a *Numerus clausus* is practiced, such as in medicine. This 'defensive' approach to the initiation of students has basically a number of drawbacks: the approach appears dysfunctional because it may exclude or drive away sizeable portions of talented students (and keep diligent but unimaginative learners), it postpones active learning and the contact with research, and it prolongs studies (and the subsequent phases of professional development).

Admission management, if properly administered, selects students which are capable to pursue their chosen studies.

From a European perspective, admission control or admission management is discussed under the heading of *Numerus clausus* and has a negative connotation[16]. There is an implicit notion that admission management is unethical from a democratic, social-state point of view[17], a view which is probably based more on misunderstanding than on proper analyses. As we have pointed out, admission management bears the danger of discriminatory practices, which have to be monitored and controlled. But it would be naive to think that open access practices are inherently less discriminatory. Two examples may illustrate our point.

- The first refers to the admission policy of the University of California System, a public university (see Tables 8.3 and A.13). While we cannot review the admission policy of the California university system in detail, of course, one can at least show that the university system there pays some attention to its ethnic composition[18].

- The second example refers to the open admission policy of the Swiss universities and the high school graduation rates in selected municipalities of the District [Kanton] of Zürich (see Table A.14). The example shows that children of well-to-do families have a much higher chance to attend a university than the average person of the same age group: the chance is twice as high (and perhaps three times as high as compared to a person having grown up in a low-income household). While there is some correlation between the income (of parents) and the cognitive abilities (of their children), children of well-to-do families appear well over-represented in Swiss universities.

[16]If one looks into the recent history of US higher education, similar negative connotations can be detected. See e.g. the various references concerning discriminating admission practices in [77]; or see [59].

[17]We should note here that admission management is a different matter than the setting of tuition and fees for students.

[18]When comparing the figures of Berkeley and the rest of the UoC-System with the entire State, please pay attention to the percentages listed under 'other and unknown' which are present in the first two columns but not in the third.

Table 8.3: UNIVERSITY OF CALIFORNIA: Enrollment by Ethnic Group, in % (Year 2000); 'other UoC' refers to all institutions of the University of California Systems (except the UoC at Berkeley), and 'State' refers to the ethnic composition of the entire State of California (year 1999); based on Table A.13, www.dof.ca.gov and [192].

ETHNIC GROUP	Berkeley	other UoC	State
Whites	30	37	51
Hispanics	10	13	30
Asians	45	37	11
Blacks	4	3	7
Native Americans	1	1	1
other and unknown	11	9	—
Total	100	100	100

8.3 Reforms of Governance and Management

We are, of course, not the first to see these differences, not the first to challenge the European — or the Swiss — university. Many have decried and criticized the European institutions or formulated their visions, in 'letters to the editor', in articles or brochures, or in entire books, e.g. academics [235, 108, 57, 224, 56, 87], policy makers [26, 121], politicians [71], industry and business representatives [52, 213], journalists [154, 233]. Because of their vigilance, and because of the proclivity of the various stakeholders involved, reforms were initiated — and reforms are being pursued right now. But we cannot rid ourselves of the impression that, despite all this constructive criticism and despite the reforms initiated, the often dismal state of the European university is not seen and the initiated reforms will not really take hold.

Reforms appear to fall short because of, basically, two reasons, as SUSANNE LOHMANN [135] remarks with regard to the university environment in general (and not only regarding the European university)[19]:

> "[external stakeholders] do not [...] understand the way the university works, their ideas about how to change it tend to be cross-cutting and contradictory, unhelpful at best, disastrous at worst."

And furthermore:

> "[...] the internal stakeholders of the university — the faculty — [...] are naturally, inherently antithetical to change. Collegial faculty governance, which relies on deliberation and consensus, favors inaction and gridlock. Worse, the faculty's values are inward- and backward-looking, concerned about protecting the tenured faculty's entitlements and preserving the compartementalized organization of the university into departments and disciplines. The result is structural and intellectual ossification."

Hence, if we are going to have reforms at all, we have to work them out within a dialectic discourse which reaches out to all who are involved. But a dialectic discourse alone will not suffice. What is needed, in addition,

[19]SUSANNE LOHMANN, Professor at the Department of Political Science and Director of the of the Center of Governance at UCLA, gave this talk at the ETHZ as well (December 18, 2001).

is a learning process, involving not only individuals but entire institutions [201, 63].

8.3.1 Historical Roots

Change processes are complex phenomena. We observe that certain processes move fast, while others are slow. We are confronted with desirable and undesirable changes — and we perceive changes and the speed with which they occur from different vantage points. In anthropogenic systems change can be viewed as a common vector of individual decisions. If we view these changes with reservations or concern — the increases of pollution, deforestation, traffic congestion, urban sprawl, et cetera —, we may perceive them as products of a "tyranny of small decisions" [112]. Frequently, such 'tyranny' is attributable to a deficient delineation of markets, to a non-inclusion of external effects in the mode of decision-making. Conversely, if we welcome or prepare for change, we ought to make sure that an environment be created, a 'culture' perhaps, in which individual decisions do not produce sub-optimal or even pathological systems behavior but contribute constructively to a desirable mode of affairs.

If we look at developments in higher education, we observe changes which are fairly uniform and in large measures necessary and desirable. We observe a general expansion of higher education, a co-requisite of knowledge-based economies: higher education spreads geographically (to formerly undeveloped countries) and expands locally (to include new population strata of the respective societies). But we also view disparities in development which are disconcerting and in large measures still unexplored. The evidence is there that tertiary education in Europe has fallen behind higher education in the US; this is particularly true as far as research universities are concerned. While there is an awareness of such gaps, its root causes appear to be seldom comprehensively addressed and, consequently, the current reform movements may not bring about the desired turn-around.

Higher education spreads geographically (to formerly undeveloped countries) and expands locally (to include new population strata of the respective societies).

Joseph Ben-David, one of the great scholars in comparative analysis of higher education, links the current deficiencies in European higher education to the former success and dominance of European science [12]. From this vantage point, the noble heritage prevented adaptations which appear necessary to be truly successful in today's world. Particularly the once so successful German university appeared unable to adapt properly to the changing conditions of mass higher education. As late as 1930, Abraham Flexner, one of the early proponents of comparative analysis, sought to fashion the American university on the German model [74]. He was enchanted by the Humboldtian idea of the university, by the scholarly orientation of faculty and students, by the organizational setup of the institutions, and by the interplay between education ministries and universities.

While Flexner was instrumental in reforms of American higher education and medical schools, particularly as far as the research university was concerned, and while he shall be remembered as an enterprising educator and one the founders and the first director of the Institute of Advanced Studies at Princeton[20], he appeared to have misread both the American and the German university of his time. In the introduction to FLEXNER's analysis CLARK KERR, the former president of the University of California system, writes [74] (p. x):

> "[…] FLEXNER was so wrong about the German universities he so revered, so wrong about how good they really were — they had collapsed by 1933 and partly of their own doing; and so wrong about the American universities he so scorned — they were on their way to becoming the best in the world."

And further (p. xxviii):

> "[…] FLEXNER did not realize how many functions can be combined within a single university — even apparently inconsistent functions. Particularly, he did not see how service functions might draw support and money to a university, so that it could perform better also in advanced teaching and research."

CLARK KERR's view regarding the German university model might be seen as a practitioner's corroboration of BEN-DAVID's studies. But Kerr's criticism goes even beyond that. It touches on various aspects which ought to form the focus of a current debate on the university: it touches on the German concept of the *Volkshochschule* as a complement — and not a part — of a university, a concept which was subject to debate in the Weimar Republic for instance[21]; and it touches in general on the universities' roles — and mission — in their respective societies and economic environments.

The German university prospered because it was in a position to expand.

While it is generally recognized that the German university became the leading model of higher education around the middle of the 19th century, surpassing the more centralized institutions in France and England in influence, it is doubtful whether the success of the German model ought to be tied so strongly to reforms initiated by VON HUMBOLDT [231], FICHTE [73] or SCHLEIERMACHER [238] at the beginning of that century. The German university prospered because it was in a position to expand. Germany had — in contrast to France and England, the leading science nations in the early 19th century — a decentralized structure and new disciplines, new arts and sciences, could develop competitively through the formation of new chairs at various universities. As JOSEPH BEN-DAVID observes [12] (p. 129):

> "The usual rule that each discipline was represented by only one professor contributed much […] to the establishment of new chairs, because the expansion of academic staff could take place only in this manner. After the development of institutes, however, the same rule became a veritable strangling noose: research could be conducted only in the *Institut*, but only one professor, the director, could be professor."

[20] FLEXNER was in this position until his retirement in 1939. Under his direction the Institute assembled a range of distinguished scholars and became host to European emigrants, such as Albert Einstein.

[21] See e.g. the discussion by MAX SCHELER [189], pp. 385–420.

Table 8.4: Governance, Planning and Management Influence, by Policy Level and Culture (US vs. European), based on [229].

	Institutions:	
Policy Level	US	European
State Government	low	high
Presidency (Rektorat), School, Department	high	low
Faculty Member	low	high

In other words, it was the concept of the *Lehrstuhl* — i.e. a professorship dedicated to a particular field of study, having the sole responsibility at an institution to develop such field — which was instrumental in the 19th century for the spreading of science. Expansion in a particular field could only take place through the formation of competing *Lehrstühle* (and associated institutes) at other universities. After this expansion period, saturation had to set in if the rules of ordination remained the same. In fact prior to World War I already, the dominance of German science began slowly to fade [12] (p. 107) and structural — or what we call morphological — limitations came to the foreground (p. 135):

> "The structural limitations of the German university remained latent so long as role-differentiation permitted the continued expansion of the academic profession, but once the *Institut* blocked the path toward professional chairs, the inadequacy of the structure became manifest."

In this view, German science — and the Humboldtian university model — did not primarily loose its prominence because of the Nazi catastrophe and the emigration or destruction of an entire generation of undesirable scientists [127], but due to an insufficient adaptation to a time in flux. This is what Max Perutz meant when he recounted his anecdote about Fifi (see the Foreword) [152] (pp. xi-xii). While today's Humboldtian universities may have a softer stand on the concept of the *Lehrstuhl* and the fields they consider *ordinierbar*, there can be no doubt that the original concepts still play a role, despite their dysfunction. Joseph Ben-David concludes that "The European conception of the university is [...] woefully out-of-date" (p. 156). Furthermore, he states that (pp. 156):

> "[...] the long term success of university reform in Europe will be dependent on the establishment of much less hierarchic and much more decentralized systems of higher education and research than those existing in England and France and a much less authoritarian and much more flexible university structure than that existing in Germany."

8.3.2 Foci of Current Reforms

On the backdrop of this historic sketch we shall try to trace the outline of current reforms in Europe. We shall focus first on the German situation — because of its strong impact on higher education systems adhering to a so-called Humboldtian tradition.

We have already pointed out some of the more fundamental differences between public US and European (continental) institutions (see section 8.1, Adaptation Processes). Some of these differences have diminished, due to reforms which have already been initiated, but — despite the reforms — the differences are basically still prominent. One significant difference pertains to the form of governing an university (see Table 8.4). As we compare the basic modes of governance in the US and in continental Europe, at least those that were prevalent around 1990, we can see an almost opposite approach. While the European institution is characterized by (relatively) strong government ties and a (relative) autocratic faculty, the corresponding US institution is characterized by a higher degree of autonomy and by a more collegial form of self-organization. These differences build upon and reinforce the morphological differences which separate the universities on both sides of the Atlantic (see Chapter 7).

Reforms in Germany As we read the newer reform proposals pertaining to the German university, for instance, we might notice a reluctance to basic and effective changes — or misguided notions on how such changes should occur [28]. This impression does not vanish even if we perceive the initiated measures as steps along a path to more substantial change. Granted, many of the major goals underlying the current reforms — the consequent pursuit of non-discriminatory measures, the furtherance of talent and underprivileged population strata, attempts to lower the times-to-degree or the age of promotion to positions of faculty, et cetera — are necessary and noble. That the European university is holding onto the premise that access to tertiary education be provided on the basis of minimal tuition and fees, is of course of paramount importance[22]. But the basic deficiencies of the German university — the still strong government control, the reluctance to guide institutions in an entrepreneurial way, the almost feudal positions or longings of the faculty and the concomitant social distance separating students and faculty — appear insufficiently addressed.

We notice a reluctance to basic and effective changes — or misguided notions on how such changes should occur.

The Framework Act for Higher Education, as the new German *Hochschulrahmengesetz* is officially called[23], regulates in a 21-page document the following: (i) the basic purposes of institutions of higher education, particularly regarding education and research (6 pages); (ii) the admission of students (4 pages); (iii) faculty and staff membership (8 pages); and (iv) legal basis and autonomy of institutions (3 pages). The *Hochschulrahmengesetz* serves as a frame for corresponding laws issued by the respective *Länder*. We cannot analyze this new law in detail, but a few remarks may illustrate our impression:

[22]However, holding onto this premise without the implementation of corresponding corequisites might destroy the last remnants of a basic high-quality education. There are strong currents in Europe to give up low tuition and fees, in the hope presumably, that higher tuition and fees will enhance the quality of education as well as the motivation of the students: a fallacious argument in our view. It is interesting to see which reforms are in the foreground — and which are not.

[23]Passed into law February 16, 2002; see `www.bmbf.de`.

- From a 'liberal' perspective, the *Hochschulrahmengesetz* clearly over-regulates tertiary education[24]. On the basis of this law, a US institution (however esteemed) could not be transplanted into Germany and no new public institution molded after a US research university — or the ETHZ for that matter — could be created on German soil.

- The law regulates a full range of details which should not be regulated above the institutional level and delegates responsibilities to state authorities (i.e. *Länder*) which should be within the domain of the autonomy of the individual institution (or associated systems of higher education). In so doing, the law cements basic structures rather than providing a framework within which new practices may evolve and new experiments can be pursued.

- On the other hand, the law provides few stimulants to really break open the rigid hierarchy of the German personnel structure of the university, other than to postulate a new faculty position, the *Juniorprofessur* [15, 219][25]. The new law may be an improvement over conditions which existed before, particularly because it implicitly relativizes the *Habilitation* and the position of *Privatdozentur*, but the improvement appears marginal and the law may prevent future reforms (within its framework).

BERNHARD NIEVERGELT and STEFANIA IZZO [167] take note of a general reservation concerning the (planned) abolition of the *Habilitation* and trace this reservation to fears of retrenchment (p. 13):

> "Die fast einhellig ablehnende Haltung der Disziplinen gegenüber der Abschaffung der Habilitation in Deutschland hat [...] einen [...] Grund: Die prägende Erfahrung drastischer Sparmassnahmen im Hochschulbereich. [...] Der fehlende Reformwille hat also nicht nur mit den Inhalten der vorgeschlagenen Reform zu tun, sondern basiert wesentlich auf einem grundsätzlichen Misstrauen gegenüber der Reformmotivation der Politik."[26].

All in all, the new German *Hochschulrahmengesetz* appears not to be destined to lead the path to sustainable reforms, unfortunately, despite the title under which the reform law was introduced[27]. It doesn't appear to revise, in significant ways, the form of governance (see Table 8.4) which separated the Humboldtian university of the 20th century, over-regulated from above and autocratically managed from below, from the more modern peer institutions (in various parts of the world).

[24] There is no corresponding law in Switzerland, for instance, and none is planned (thus far at least: there are some discussions, though).

[25] We are not really familiar with the gestation of this position. From a distance, the position appears unnecessary, if not ill-devised and discriminatory in effect; the established position of the Assistant Professor would clearly suffice.

[26] BERNHARD NIEVERGELT and STEFANIA IZZO collected various responses regarding a possible abolition of the *Habilitation*. Some of the responses testify to the fact that the *Habilitation* is seen as a cultural heritage to be preserved — or a necessessary initiation rite. Take the following response by a law professor (p. 59): "Wer durch dieses Fegefeuer gegangen ist, wer die Risiken der Wahl des Themas auf sich genommen hat, wer die Ausdauer besitzt durchzuhalten, bis die Arbeit fertig ist, wer die Frustration, die stets mit derartigen Arbeiten verbunden sind, durchgestanden hat, ist in aller Regel ein Wissenschaftler von höchster Qualität".

[27] "Mut zur Veränderung: Deutschland braucht moderne Hochschulen", see [28].

Bologna Process A major reform process is currently underway, signed in the Summer of 1999 in Bologna by 29 European government representatives[28] and based on prior work[29]. This reform process, referred to as the Bologna Process, is trying to foster employability in the European labor market and competition in general. In this context, the Bologna Process pushes for the:

- "adoption of a system of easily readable and comparable degrees";
- "adoption of a system based essentially on two main cycles of higher education, undergraduate and graduate";
- "establishment of a system of credits — such as the [European Credit Transfer System] (ECTS) — as a proper means of promoting [...] student mobility";
- "cooperation in quality assurance"; and the
- "promotion of the necessary European dimensions in higher education, particularly regarding curricular development, inter-institutional co-operation, mobility schemes and integrated programmes of study, training and research."

Great hope is placed on the Bologna process, but its aims will have to be pursued with perseverance if educational systems are to be moved. Employability in the European labor market, mobility and the fostering of competition will depend on a range of other factors not mentioned in the Bologna declaration, and the specific factors mentioned appear only marginally instrumental. The last two of the five points listed above, those of a more general, process-oriented nature, appear to have greater weight than the three more task-oriented recommendations. Specifically, institutional cooperations and alliances will play significant roles in the future[30].

But the other three recommendations hold promise as well. The second recommendation concerning the establishment of a system composed of two main cycles, undergraduate and graduate, is valuable if properly pursued by institutions: it would allow to structure curricula better according to the needs of an increasingly diverse student population; it would provide the basis for the formation of formal graduate schools in Europe and it would, in the interpretation of some, allow for an active admission management on the part of the institutions, at least at the graduate level[31]. The first recommendation can be read as a corollary of the second. And the third recommendation is probably not that valuable in the promotion of mobility, but it is instrumental in the context of institutional resource allocation and budgeting [237, 147] — and, hence, instrumental in the context of autonomous institutions[32].

[28]Joint declaration of the European Ministers of Education, Convened in Bologna on the 19th of June 1999 (Bologna Declaration); see `www.unige.ch/cre`.

[29]Such as the Sorbonne Declaration of May 25, 1998.

[30]An example of such an alliance is the IDEA Leage which covers the following four technically-oriented research universities: Imperial College, Delft University of Technology, ETHZ, and RWTH Aachen.

[31]ETHZ's Rector Konrad Osterwalder, who is actively involved in the Bologna process, is a proponent of this position.

[32]This is probably an unintended consequence of this particular recommendation.

Prospects While reflecting on the present state of affairs in higher education, much hope is placed on future technologies — or present technologies in their embryonic stages. While we embrace current and prospective technologies in the context of higher education, and while we support the 'virtual campus', we doubt whether these technologies will play a vital role as solvers of the issues addressed in this Report. Since we have already sketched the prospects of the 'virtual campus' elsewhere [102], we shall refrain from sketching them here again — other than to add some concluding remarks. We share NEIL RUDENSTINE's skepticism when he states [187] (p. 124):

> "No one should believe that electronic communication can be — or should be — a substitute for direct human contact."

And he explains (p. 123):

> "We know that the constant exchange of ideas and opinions among students — as well as faculty — is one of the oldest and most important forms of education. People learn by talking with one another, in classrooms, laboratories, dining halls, seminars, and dormitories. They test propositions, they argue and debate, they challenge one another, and they sometimes even discover common solutions to difficult problems."

This skeptic position is also taken on by JAMES DUDERSTADT, the former president of the University of Michigan, when he states [62] (p. 281):

> "The idea of a cyberspace university has its limitations. For many purposes a strong residential component is critical, especially for our undergraduates."

CHARLES VEST, the current president of MIT, proposes both futures, as complements to each other [230]:

> "The issue is simply stated. Does the future of education, learning, and training belong to a new machine-based digital environment, or will the best learning remain a deeply human endeavor conducted person-to-person in a residential setting? I believe the answer is 'Yes' — to both. We are at the proverbial fork in the road where we should, and will, take both path."

And he continues:

> "But there is even less doubt in my mind that the residential university will remain an essential element of our society, providing the most intense, advanced, and effective education. Machines cannot replace the magic that occurs when bright, creative young people live and learn together in the company of highly dedicated faculty. The residential research-intensive university will not only survive, it will prosper. If anything, its importance will grow as we continue to provide access to the brightest young men and women regardless of their social and economic background."

To conclude, while we support the new technologies as vital — and necessary — elements of higher education's future, the various problems or issues we have referred to in the general context, e.g.

- mass higher education, funding issues and retrenchment, diversification, accountability and governance, et cetera,

and the problems or issues we have referred to particularly in the European context, e.g.

- performance-based budgeting, governmental control and institutional autonomy, productivity and effectiveness, management and organizational issues, abolishment of feudal vestiges, professionalization of administrative staff, mobility, et cetera,

will not be solved and cannot be addressed primarily on the basis of technological solutions. All these issues and problems will have to be confronted head on, with perseverance, insight and compassion — by enlightened academic leaders, by faculty and students, by politicians and political parties, and by institutional researchers. There is no need to look for solutions in a nebulous technological future: there are enough examples around attesting to managerial practices worth emulating. There is much at stake, not the least the future of our children.

Part II

Commentaries and Rejoinder

Chapter 9

Comments and Reflections

If education is to produce scholars [...] it must include [...] the training towards original thinking*; it must help develop a reliance on individual judgement, sense of justice and truth, and conscience.*

Imre Lakatos [159]

Several representatives of higher education and institutional research were invited by CEST to respond to a Discussion Version of this Report[1], as presented in Chapters 2 through 8 (Part I: "A Basis for Discussion"), plus the Foreword[2]. These representatives, members (or former members) of academia, were asked to provide "feedback on the issues presented", to be included in the Final Version of the Report — in addition to "pointing out possible factual mistakes". Some of the commentaries CEST received are presented below, i.e. those where we have received permission that they be published, with few editorial changes: some side remarks were omitted, indicated by [...], some editorial changes were added — in square brackets [additions] — where we thought the addition would enhance the understanding of the text, and few editorial corrections or changes were made (regarding orthography and the unification of spelling, etc.).

9.1 US Commentators

9.1.1 Herbert H. Einstein

This is a well documented report. The statistics alone make it worth reading, but it is also interesting to see how two high-level universities compare with each other. My comments below are limited to the critical ones and, when reading them, the [reader] should keep in mind that much of what [the authors] say in the Report is pertinent and important.

[1]Dated June 25, 2002.
[2]Letter issued by CEST, June 27, 2002.

General Comments The Report says in the introduction and in the executive summary that it is a comparison, but it only mentions very marginally what this comparison should — or might — be used for, apparently using MIT as a benchmark for ETHZ? By implication (through the comparison with the auto industry) and as alluded to throughout the Report, this might mean that the MIT example could be used to 'improve' ETHZ. I have two comments about this:

- If this is the purpose of the Report, it should be said so directly and not obliquely.
- This is actually much more important [...]: It is very dangerous to use a comparison between existing structures or processes to make improvements. The best one can do on this basis is to catch up to some extent. One will never catch up completely and one will certainly never overtake the 'better institution' (vide Japanese/US auto industries). An important part of the study should, therefore, have been to compare where MIT/ETHZ are or might be going. Clearly I may have misread the intentions of the Report but if it is 'only' a comparison of the present situation, then this should be clearly said.

What makes universities are the people in them and how they interact.

Strongly related to the preceding comments is the fact that the Report concentrates on things which can be evaluated by numbers (including the use of the questionable citation index) or by organizational structures. This lets one easily forget that what makes universities are the people in them and how they interact. [In] my opinion, the best part of the Report [is] where the structural ('morphological') features — facilitating human interaction — are described and commented upon. This is, however, only a small section of the Report. Much more emphasis should have been placed on the social environment, although much of this would have been more qualitative. It is very revealing in this regard that under "change management" examples from Switzerland and Germany are given but not from MIT nor from the US in general. Maybe this is it: The need for change management, or the perceived need for change management versus the continuing self-renewal, is the main difference between ETHZ and MIT?

Undergraduate vs. Graduate Education Again related to looking at the present and the past: The US research university grew out of the technical/scientific activities of World War II and got another push through the Sputnik crisis. While this system seems to have done very well so far with regard to doctoral students, it is by no means so sure that undergraduate education has benefited from it. So the question arises if universities should be judged by their production of researchers and of research or by a wider ranging contribution to education. The Report, in my view, should, therefore, have put much more emphasis on undergraduate education as well as on outreach.

Regarding education in Liberal Arts (Humanities, Social Sciences), [...] the philosophy and some practical aspects are quite similar at MIT and ETHZ.

Students should be exposed to such education and they are forced [at MIT] to take [one] course per semester. (I am not sure how much 'forcing' there is at ETHZ today. When I was [enrolled at ETHZ] we needed to sign up and then could — or could not — attend. I usually took at least two [courses] per semester and actually did quite a bit of work, and I was by no means the only person doing so.) It is actually quite beside the point if one does much graded work in these courses or not. Many of them attract students through the faculty who teach them ([the authors] mention [Karl] Schmid; there were also many eminent historians at ETHZ, e.g. [Karl] Meyer [1928-1946], [Jean-Randolphe] de Salis [1935-1968]). Is this not what education should be?

Structural Development at ETHZ Given that this Report should also 'teach lessons', it should have discussed the "failed matrix experiment" at ETHZ much more extensively (see Section 3.2). This is a prime example of what can happen when one does 'change management' on the basis of lacking knowledge and understanding. [In the same section, the] comments about the merger of 'civil engineering' and 'rural engineering and surveying' are not quite correct. The two [divisions] were merged by a decision of the ETHZ management. There was quite a bit of resistance amongst some faculty. This happened when the matrix structure was abandoned, but [it] had not much to do with this except for providing an opportunity.

I think [the] statements [about research fragmentation] are much too general. It might appear that MIT has much stronger and more interdisciplinary research than ETHZ. This may be so on the surface and may be actually correct in some cases. In most instances at MIT, it is "get the research, then divide it up". This entire issue requires quite a bit more investigation since it also depends on the specific research domains. Finally, it needs to be made clear what is meant by internal and external funding. At ETHZ, internal funding apparently means funding automatically allocated with the annual budget and not much control by the ETHZ administration, while at MIT internal research funding is not 'automatic' and involves competition and control by the MIT funding entity.

Bibliometric Measures Publication — and citation — counting is not very reliable. For instance, the citation index in the past did not include many engineering publications. Also, there are very different standards regarding 'shingling' between engineering and the sciences[3]. [Furthermore,] I [...] don't quite understand why output is judged on the basis of publications, prizes, awards and degrees. Particularly in engineering there are other aspects, something the Report marginally recognizes by mentioning Christian Menn [see Chapter 6, "Focus on Output"]. Also, I do not understand at all why impact on practice — be that through spin-offs or new technologies — is not considered. This is a significant flaw.

[3] 'Shingling' means the reporting of the same research results in different publications. In Science it is entirely acceptable to have a short publication in e.g. *Nature* or *Science* and then a more extensive one in a specialist journal. In Engineering such overlaps of subject matter in different journals is not liked and in most cases deemed unacceptable.

Comments Regarding Particular Aspects [Herbert Einstein provided further comments on particular points of the Report; most of those are listed below:]

- *Admission Management* (Section 5.1): The selectivity of MIT and its possible role in increasing the female/minority enrollment would have deserved a more detailed investigation. Also, the large female undergraduate enrollment is one of the major differences between MIT and many other engineering universities, and this also should have been discussed.
- *Student-Faculty Ratios* (Section 4.1.1): The student-faculty ratios at MIT should be more carefully differentiated. The numbers should distinguish between Undergraduate students, MEng/M.Sc. and Doctoral students. The advising/supervising load is quite different between these categories.
- *Thought Experiment* (Section 7.1): This "thought experiment" is well chosen and points to a major difference. There is an additional point, however, which is the much greater competitiveness in the US system. Some of this may have to do with the fact that once a European professor has his [or] her job, he [or] she is 'secure', and this includes the [funding of the] staff (funded by internal money). The competitiveness in the US system is much greater and it even includes teaching. The interesting fact, which could be the subject of a separate study, is that in spite of this inherent competitiveness, there is usually much more congeneality in the US than in the European system! The flip side of the competitiveness, however, is the toll it takes on private lives. The quality of life issue is a much greater problem in the US and at MIT in particular than at ETHZ! Again an issue which should have been looked into.
- *Helvetic-Retardation-Effect* (Section 8.1): The comment about the 'helvetic retardation effect' is wrong. As a matter of fact, the *Globuskrawalle* in 1966/67 preceded and occurred simultaneously with the Berkeley protests. The *Opernhaus-Krawalle* were the predecessors of what eventually led to freedom for Eastern Europe. A careful study of Swiss history, and this is very interesting, shows that unrest in Switzerland preceded what occurred later in other countries. One can naturally argue that the Swiss unrest had not much of an effect but even this is only partially correct.
- *Conservative Faculty* (Section 8.3): I fully agree (and I have said so when I gave [a] talk at ETHZ a few years ago) that there is nothing as conservative as university faculty. One has to put this into the context of human behavior. Both as individuals and as groups, one needs a solid and quiet base if one wants to do really revolutionary things!

Personal Reflections Having very close ties to both universities, it is interesting to see this comparison. This is particularly so, since one of the first things I was asked to do here [at MIT] in 1966 was to come up with a method to assess research output. (I took mostly management courses at that time.) This was in the heydays of research, and the fact that one of my mentors wanted to look into this — when it was actually not necessary — reveals a lot about the faculty at MIT. This is closely related to [Jay W.] Forrester's comments about what MIT should do: When a problem area is generally recognized it is time for MIT to get out of it. On the other hand, ETHZ does things 'right', also: The ETHZ students, who I knew and know, who continued their studies at MIT were usually at the top!

9.1.2 Susan H. Frost and Paul M. Jean

Economic, social, and technological changes across the world have created an ever-expanding appetite for the kind of professional education and sophisticated research that universities provide for students, industry, and government. Even as their roles expand, institutions seek to shape their destinies in innovative ways while maintaining the core of their academic values.

During this shaping process, important questions arise about the direction and form of change. To help address these questions, The Center for Science and Technology Studies (CEST) has charged scholars at two research universities with providing a cross-national and cross-institutional analysis. Their resulting comparison of ETH Zürich with MIT is rich in valuable information and insight and succeeds in capturing important differences between both institutions in productivity and morphology. We congratulate the authors for their skill in comparing MIT, a uniquely positioned, elite private US university, to ETHZ, a Swiss public institution with an open admissions policy. Even when two universities share national location and similar funding mechanisms, such comparisons are difficult at best. By describing important differences between the institutions, Herbst, Hugentobler, and Snover have advanced knowledge of institutional development at those two universities and at others as well.

Our charge is to critique the study, and we do so with two aims: to strengthen the impact of the study on decision-making at both institutions and to contribute to the important scholarly debate the authors have framed. Based on study of our own institution as well as our understanding of recent scholarship, we focus on how the authors address the big picture: the relationships between form and function and between adaptation and institutional context. First we summarize some key ideas about institutional adaptation in recent literature. Next, we note some ways the Report might provide a stronger platform for development at the two institutions. Finally, based on our experiences at Emory University, we describe some ways a deep understanding of local culture and context has guided Emory's development and how ETHZ and MIT might use such techniques.

Scholarship on Adaptation and Change Three scholars who have helped us understand how universities develop are Burton Clark [40, 42], Jonathan Cole [47], and Barbara Sporn [209]. Clark is an eminent scholar who has studied universities in the US and in Europe over the course of many years, Cole is a sociologist who has served as provost of Columbia

University since 1989, and SPORN is an Austrian scholar who has compared universities in Europe and the US. Each suggests that successful change requires balancing innovation and adaptation with maintaining strong core structures and values.

In 1993 COLE noted that the roles and functions of the modern university are expanding so rapidly that institutions can no longer cover all areas of knowledge. He recommends that universities name their arenas of comparative advantage and invest in those, even if this strategy reduces investment in other areas. SPORN took these ideas to another level in 1999 by looking at adaptation in European and US universities. She found that differentiation among competence fields is a common response to environmental demands. The differentiated units are accountable for their activities and are free to design and adjust services to meet expectations and needs.

Universities should name their arenas of comparative advantage and invest in those, even if this strategy reduces investment in other areas.

For CLARK, institutional transformation depends on increasing innovation at the periphery, access to diverse resources, and support for a strong academic core. Universities need to infuse development of new structures and cultures with a strong sense of purpose and guiding principles. Taken together, the ideas of CLARK, COLE, and SPORN suggest that universities should combine attention to the core with specific efforts to form and support excellent, highly differentiated programs. If used wisely, the resulting combinations can become the ingredients of institutional distinctiveness.

Other scholars suggest the importance of using contextual knowledge of attitudes, values, and practices to guide an institution's future. In addition to looking outward for models to emulate, these scholars describe how looking inward at the historical and cultural evolution of an institution provides a strong foundation for change. PATRICK TERENZINI [217] labels this kind of deep learning "contextual intelligence". HENRY MINTZBERG [155], PETER DRUCKER [61], and LARRY HIRSCHHORN [103] have described how acquiring a deep knowledge of an organization enables leaders to challenge old assumptions and articulate new visions that tap into the passions and aspirations of its members.

Linking Institutional Morphology to Purposeful Outcomes When considered together, these scholars suggest that successful universities change not merely to be different or to emulate other institutions, but to advance their own particular mission and vision. When facing new demands and pressures, successful universities develop new ways of differentiating themselves while strengthening their academic core, aligning these actions with anticipated outcome. Although HERBST, HUGENTOBLER, and SNOVER claim that their study is of "limited scope", they have compared MIT and ETHZ successfully. It therefore seems to be a natural next step to speculate more about what kinds of structures and morphologies at MIT and other US universities might help ETHZ and other European universities.

In their executive summary, the authors speak of a "mismatch between higher education institutions and their surroundings", noting that many European institutions have failed to meet the new demands on colleges and universities (see page 15 of the Report). MIT and other US institutions have achieved greater productivity in response to new demands than ETHZ and other European institutions, the authors argue, and so ETHZ should emulate MIT in some ways.

We do not always get a clear picture of which MIT morphologies and structures ETHZ might adopt, however, and which of these might work in their unique local and national context. We are left asking: Which of MIT's practices would improve productivity at ETHZ, and why might this be the case? How would MIT's structures fit in with the specific missions and environmental contexts of ETHZ? Describing how and why adopting certain aspects of the US model would improve specific outcomes at European universities might help decision-makers at those institutions go forward.

Successful universities change not merely to be different or to emulate other institutions, but to advance their own particular mission and vision.

For example, when the authors point out the differences in organization around disciplines and departments (page 18), the reader is left to determine why the school/department organization of MIT is superior. According to the authors, ETHZ is more fragmented than MIT because it has more units. MIT's units, however, "have an interdisciplinary orientation", leading us to wonder how the MIT structure might increase productivity at ETHZ. The authors link structure to outcome successfully when they describe how low staff-faculty and student-faculty ratios help "faculty work in smaller teams …[and that] research administration is limited in scope, hierarchies are flatter, and faculty have colleagues alongside with whom to share ideas and problems", reducing "social distance" and increasing "mutual respect" (pages 15 and 83). Although hypothetical, speculating about the linkages between morphology and outcome would strengthen the Report.

Contextual Knowledge and Adaptive Change For ETHZ and other European universities that wish to emulate the successful ways US institutions adapt to change, understanding structure and morphology represents a valuable starting point. The MIT and ETHZ Report succeeds in capturing important differences between both institutions in productivity and morphology. By exploring in greater depth the link between environment, structure, and institutional goals and values, the authors could strengthen and expand the reach of their ideas. Additionally, our study at Emory suggests that linking institutional morphology and structure to productivity outcomes based on comparative data reflects only part of the story.

The scholars we used to inform our comments about this Report also have guided our study at Emory, another research university in the US [79]. Unlike MIT and ETHZ, Emory is not a technological university. It is a broadly-based private research institution with a liberal arts core and a large academic medical center. Although there are important differences in the three universities, we believe our work at Emory offers some relevant lessons about institutional change.

For example, several qualitative studies about program-building strategies that seem to work well at Emory suggest that effective support for scholarship occurs best at the grass-roots level and not at the level of centralized bureaucracy [81, 82, 80]. Across these studies, we observed that nurturing the intellectual passions of faculty and the collegial networks that support and stimulate those passions help collaborative activity to flourish. For example, a study of an eight year faculty seminar program showed how investing in sustained and scholarly intellectual discourse across academic fields can influence teaching and research in ways we judge to be more powerful than typical administratively-created faculty development programs. Another study of the genesis of cross-disciplinary intellectual initiatives revealed how faculty interests and interactions helped build momentum. Nurturing these connections while reducing administrative barriers enables such initiatives to develop successfully.

Given Emory's decentralized administration, the best tools for enhancing scholarship seem to lie in supporting faculty autonomy and collegiality and reducing administrative burden. Deepening our understanding of the beliefs, values, and practices of our faculty has helped guide our own institutional morphology in support of our goal of enhancing interdisciplinary work and strong intellectual community [84].

Concluding Note We believe that contextual knowledge about the dynamics of internal and external culture helps complete the picture provided by understanding morphology and structure. Such knowledge, for example, might help leaders understand the overarching beliefs and values that faculty and decision-makers at ETHZ and at MIT uphold, positioning the leaders to ask: How would proposed changes in organization and resource access strengthen or challenge these beliefs and values? What traditional structures and policies have worked well in the past and should be kept or adapted? What new structures policies would provide greater autonomy and innovation while meshing with the local context, goals, and identity of the institution?

Effective support for scholarship occurs best at the grass-root level and not at the level of centralized bureaucracy.

The MIT and ETHZ Report takes a big step forward by examining the relationship between form and function, on the one hand, and institutional effectiveness, on the other hand. Although possibly outside the bounds of this study, cogent speculation about the 'what', 'how', and 'why' of this relationship, particularly in light of knowledge about institutional culture and context, would not only help leaders to strengthen the academic core, but also to guide their universities toward distinction, comparative advantage, and effective adaptation.

9.1.3 Terrence R. Russell

The comments below are intended to stimulate discussion of a very interesting and useful piece of work. Some comments are in the nature of 'next steps' […]. [Terry Russell adds a detailed list of comments, some of which are of an editorial nature (and not contained in the following), but most are included in what follows.]

Comments on the Executive Summary Although the equivalency of funding between MIT and ETHZ is mentioned in several different contexts (e.g. sources of revenues, total revenues, research revenues and expenditures, academic expenditures, etc.) I could find no detailing of the amounts, nor a discussion of the mechanisms (mandated vs. competitive, for example). Such a discussion could give some insight into the ways that individuals and departments are tied into the national peer review processes on the one hand, into mandated governmental research funding programs on the other, and for both institutions, how ties to industry are created at the investigator level and managed at the institutional level.

While attention is paid to undergraduate or diploma-level education, it's not made clear that these students have much impact on the research outputs under consideration (more will be said about this below), nor is there a good account of graduate student/doctoral student recruiting practices, geographic range of recruitment and student qualifications.

The point concerning governmental accountability is a key one, and might warrant a discussion of the arrangements and relationships with government and other patrons who fund MIT with little or no demand for accountability. These arrangements are, I think, becoming unique to elite private institutions and the fact of their private status provides, for US audiences, a powerful ideological argument against 'meddlesome' accountability requirements. I note too that the patron role is much in decline in the case of public institutions, although the burgeoning development and fund-raising programs (in the manner of private institutions) in public universities is working very hard to develop a new class of patrons.

The professionalisation of university governance and administration was described, in the US case, by William F. Massy as an outcome of the power of well-funded research faculty to maximize control over the way they spend time. For most faculty, this meant less teaching (especially undergraduate), less administration and more research. This 'academic ratchet' (the better you are, the less control the institution has over you) is paralleled by the growth of the 'administrative lattice', the specialization and professionalisation of a wide range of institutionally necessary activities once the province of the faculty. This builds on a general notion of organizational efficiency and effectiveness driven by an increasing division of labor and concomitant deepening of specialist training and knowledge. A discussion of how the dynamic plays out in the different structure of ETHZ would be interesting.

Comments on Organizational Structures and Institutional Foci In the MIT model, funds are not "redistributed" (see page 36), they are distributed from the outside on the basis of a competitive research model. What would be interesting would be a look at the ways recovered indirect costs are conceptualized and distributed in both MIT and ETHZ.

It would be good to have some discussion of the ways doctoral students and post-docs are funded.

Comments on Focus on Output Various bibliometric measures: Co-citation analysis would be useful in this comparative case, for it would give one an idea of the extent to which large research groups differ from small ones (if at all) in the degree of internal citation, and for external citations, a measure of the span of the 'invisible colleges' the groups are part of (as well as a measure of 'paradigm closure'?). [...]

In judging doctoral degrees as an output, the usual (and hard-to-get) measures are the quality of institution in which graduates are placed (the more closed and ascriptive the system, the less use this is) and future performance (research revenue, publications, citations, prizes and heuristic power of the work).

Patents as an output would be interesting, with some discussion of how the institutions manage patents (beyond the one MIT reference), and industry involvement.

Comments Focus on Input The relationship of undergraduate/diploma students (quality, numbers, etc.) and outputs, especially research outputs needs to be more fully discussed. In terms of quality, the presentation of the general abilities of a range of national samples doesn't seem very informative in the context of these two universities. Clearly MIT doesn't deal with ordinary US high school students nor, given the comparatively low high school graduation percentages shown for Switzerland, does ETHZ, with its nominally open admissions charge. Some discussion of both institutions as global in their recruitment, with an indication of where the foreign students come from, would be useful.

What are the comparative recruitment practices for doctoral students? Do practices differ by discipline? Who controls the funding decisions for graduate students support — the Professor, department or the institution? What are the comparative recruitment practices for post-docs? What are the comparative recruitment practices for young faculty?

Comments on Focus on Processes The finding that ETHZ has low levels of field-switching among students is important and should be emphasized.

In addition to time-to-degree for doctoral students the future comparative calculation of time-to-first-professional-job would highlight early career stage issues (e.g., the fate of post-docs or equivalents) in both systems.

Comments on Productivity Issues The role of graduate students and post-docs should be clarified.

Looking comparatively at the way undergraduate teaching is handled, note that, in US research universities, undergraduate teaching is its own specialty, and research faculty spend little, if any, time in this activity (see the 'academic ratchet' above). For purposes of this analysis, these teaching faculty might be subtracted from the research faculty numbers, or else a discussion of how (and who) undergraduate instruction is handled at MIT and ETHZ. With relatively elite students, these faculty may spend more than the usual amount of time on undergraduate instruction.

Among the efficiencies of small groups should be included the ability to close down or redirect small research groups with a minimum of dislocation and personnel upset, especially if the groups are staffed by transient graduate students and post-docs. Gunnar Boalt once said after establishing — and disbanding — three groups at Stockholm, that establishment was the easy part and the constant search for resources to keep the group going and then finally disbanding the group were the hard parts.

Another efficiency of the small group is new investigator start-up cost, which will be lower for the single principal investigator assisted by doctoral students and post-docs. By and large, US institutions follow a venture capital model, where the new investigator is given funds to create a laboratory and then is expected to generate considerably more money (and a fairly constant stream of it) to support not only his or her group, but through the overhead recovery process, the institution more broadly, including the provision of the next round of start-up money. If the expected flow of funds doesn't follow, it makes for a relatively brief career at a major research university.

Small groups make the change process easier.

There should be some consideration of the role of competitive funding and encouragement to redirection. In the competitive circumstance, a national research agenda and priorities within a particular area (and hence the chances of getting a particular project or line of research funded) are going to be defined by some mix of political priorities, peer reviewer priorities, institutional priorities and investigator interest. Small, relatively temporary, groups make the change process easier, because only the principal investigator needs change direction, and restaffing the new direction occurs as a natural flow of students and post-docs through the laboratory.

It is not the case that small groups will stay that way, especially in today's entrepreneurial climate. However, as Boalt's comment indicated, the costs of maintaining the large group constantly ratchets upward, and the demands on the principal investigator's time and energy grow also, unless the principal investigator is able to pass the burden on to someone else (the growth of the 'administrative lattice'). This paper has provided some insight into how different institutions deal with this issue, and suggests that, in the long run, large single-topic groups collapse of their own overhead burden if it cannot be off-loaded and intertwined career commitments to a line of research make change difficult — the research staff have too many interwoven 'side-bets' to easily change research direction and fewer options than recent doctoral graduates to easily change positions.

The productivity of large groups may also vary according to the way they are differentiated internally. Are individual research roles within the large group highly specialized, or is the large group composed of smaller, parallel, identical groups? Are these parallel groups in competition? For what? Are there disciplinary differences?

From the extra-institutional macro view, the small group organization facilitates the circulation among institutions of research elites and those whom they train, through processes of employment change, post-doc placement, and new faculty hires. It is an open question whether one institution on the small group model could effectively realize these advantages except as part of a matrix of similarly organized institutions among whom such circulation can occur. If surrounded by large-group model institutions locally, such exchanges might not occur locally but on a more global scale with other, similarly organized institutions at a distance.

Given the assumed advantages of the small-group model, why does the large-group model persist? As an American analyst, I follow an old tradition of discounting tradition as a casual mechanism where organizations are concerned, and suggest what may be called a functional analysis. Hierarchical pure research institutions maintain themselves through internal disciplinary boundaries, and a complex and stable set of internal arrangements and rewards that makes life within them predictable. So long as outside funds are politically mandated to be distributed on a disciplinary basis, there is no particular impetus for change, barring political change, and academic research funding is rarely a public issue.

Given the assumed advantages of the small-group model, why does the large-group model persist?

The only other motive for change would be that driven by the internal dynamics of the discipline, but for a line of inquiry to die out, a point at which there are no new questions must be reached (I leave aside that the usual circumstance of the death of a line of inquiry is a result of the death of the practitioners). As the socio-linguist Harvey Sacks said: "The text is inexhaustible". While rarely applied to scientific inquiry, the point is clear. The pursuit of (in a Kuhnian vein) 'normal puzzles' leads to the formulation of newer puzzles and the group continues. This is not an attribute solely of large-group research, but the matrix of conditions supporting large-group research makes it more likely in that situation. Part of the matrix is the difficulty of protecting careers by redistributing people from a closed-down group among other, similarly insular groups within the institution.

9.2 European Commentators

9.2.1 Aant Elzinga

The Report gives a timely comparison of two of the world's leading technological institutes. It does so with an eye to their academic cultures, organizational makeup and what bearing these have on various forms of performance, as indicated by a set of input and output indicators. The concept of morphologies to refer to structural characteristics in the two cases is definitely fruitful and helps put the finger squarely on a number of structural deficiencies of the Swiss and ETHZ academic systems. These deficiencies have already been pointed out by previous reports and evaluations, but the concept of morphological comparison and its application in the present study advances the discussion in perceptive and constructive ways.

MIT is found to be more efficient and effective in achievement of prestigious prizes and publications while graduation of doctoral students is more or less the same at ETHZ and MIT overall. MIT's higher rate of prize and publication outputs, it is argued, has to do with its much lower student-faculty and staff-faculty ratios. ETHZ on the other hand is dominated by a traditional academic oligarchy of professors, a situation that is, furthermore, marked by cognitive fragmentation, greater academic hierarchy and a cleavage between a small number of highly productive professors and a large number of less productive members of the *Mittelbau*, the latter lacking adequate resources and also autonomy.

This […] entails greater inflexibility in the face of demands on academe to respond to changing societal needs, especially those of industry, but even civil society. It also means that the humanities and social sciences are still locked in a traditional mode of being add-ons in a predominantly natural-scientific and engineering culture, with teaching until recently relegated to after-five (PM), and no Ph.D-programmes of their own. The old style Humboldtian approach also, in the present situation, constitutes an inertial factor when it comes to appropriate leadership requirements.

> *Humanities and social sciences are locked in a traditional mode of being add-ons in a predominantly natural-scientific and engineering culture.*

Overall I find the diagnosis to the point. It confirms earlier findings, some of which are even more extreme when it comes to the Swiss university system. The ETHZ is, after all, more in tune with the times than the cantonal arrangements.

In general I think the authors could benefit by consulting some of the earlier reports and evaluations of the Swiss university landscape. I am particularly thinking of the evaluation of eleven humanities disciplines, a report commissioned by the predecessor of CEST, the *Wissenschaftsrat*. The GEWI-report [197, 198] in the *Politique de la Recherche* series of the Swiss Science Council (now Science and Technology Council) touches upon the differences in publication patterns between academic oligarchies and members of the academic *Mittelbau*, and there one sees striking differences, with the former being internationally oriented and visible while the latter are sometimes publishing in more domestic and local arenas. Even if those findings pertain to the extreme case of the humanities, where tradition holds a still heavier Humboldtian hand, it would be interesting to compare something similar for the ETHZ institutions and disciplines. This would provide a further aspect in the discussion of the effects of the traditional 'morphology' at ETHZ as compared to MIT.

Another report worth looking at is the evaluation of the situation of the humanities and social sciences, as commissioned by the ETHZ Board of Government in the wake of its Strategic Vision. The latter is referred to in the "MIT and ETH Zürich: Structures and Cultures Juxtaposed", but the evaluation by the panel led by Max Kaase is not. Certainly it should be available from the Board or its Planning Commission. Consultation of the Kaase-Report might help to further substantiate and deepen some of the important points made on the role of the humanities and social sciences. In the Kaase-Report too the structural discrepancies are discussed, particularly when it comes to gaining greater response and flexibility over traditional disciplinary lines and seeking to promote humanities and social sciences in a more integrative role at ETHZ.

Finally, the experiment of the Collegium Helveticum, which started five years ago, and is designed to take an integrative approach to humanities and social science teaching and research in the ETHZ setting ought to be taken up and commented in the present Report.

9.2.2 Michael Shattock

I congratulate the authors; they demonstrate wide reading and they pull together some very interesting information. I found it enjoyable and stimulating to read.

While recognizing all the difficulties I would have welcomed some financial comparisons — the word resources appears only once [...], and then in a rather ambiguous phrase. I think it is essential for the reader to have a statement of how the two institutions are funded and a breakdown of their most recent set of accounts. I would then like to see some analysis — how much is grant and contract money, interest on endowments, general income, etc. with some assessment of the relative cost per student. It is stated that ETHZ's [student-faculty ratio] is some three times worse than MIT's, but the implication is not drawn out as to how this affects performance and in particular performance in defined areas. Without a financial dimension the Report tends to lack substance.

I would have welcomed some closer comparison of subject mix broken down into graduate and undergraduate and into staffing numbers; I simply do not know how MIT and ETHZ compare in the fields they are successful in or whether there are some areas which are particular to each institution. For example, I assume that MIT remains big in military research but that ETHZ does nothing in this area; how does this research affect MIT's academic profile and its ability to spin out companies?

9.2.3 Ulrich Teichler

Die Studie ist zweifellos ein interessantes Dokument: Die Autoren zeigen, welche Möglichkeiten bestehen, vorhandene oder durch Verwaltungsaktivitäten leicht erstellbare Daten indikatorisch zu verwerten; den Autoren gelingt es, Wissen aus dem Bereich der Wissenschaftsforschung und der Hochschulforschung, die meistens getrennte Wege gehen, produktiv miteinander zu verbinden; die Autoren sind an einer zweifellos wichtigen Frage in besonderem Maße interessiert: inwiefern die Struklur des Personals und der Arbeits- und Kooperationseinheiten (sie sprechen von der 'Morphologie' der Hochschule) die Erträge beeinflusst.

Für die beiden Universitäten haben die Autoren interessantes Material zusammengetragen. Dies kann zweifellos innerhalb der Institutionen in vieler Hinsicht auch über den Rahmen der Interpretationen seitens der Autoren interessant sein.

Die Autoren sagen selbstkritisch, dass sie ein *Benchmarking* der ETHZ an dem Maßstab MIT betrieben haben und keinen systematischen Zwei-Institutionen-Vergleich. Es wird jedoch nicht geklärt, warum die Position eingenommen wurde und wie denn ein *Benchmarking* ausgesehen hätte, die nicht diese einseitige Beziehung hergestellt hätte.

Angesichts der Datenfülle und der Belesenheit der Autoren ist es schade, dass die Studie so stark von spezifischen Werten der Autoren überladen ist. Man hat den Eindruck, dass die Autoren Beifall für "ihre Predigt in ihrer Heimat-Kirche" suchen und der Irrglaube der anderen ihnen gleichgültig ist. So wird mit großer Begeisterung dargestellt, wie schön das sein kann, wenn die Forschungsteams nicht sehr groß sind, aber es wird überhaupt nicht versucht, die Gegenposition vergleichbar darzustellen, sodass die folgende Analyse dann noch als offener Vergleich erscheinen könnte. Dass viele den Titel Professor tragen, wird so sehr bewundert und überinterpretiert, als würde die Verleihung des Titels eine universelle Gleichartigkeit von Selbständigkeit verleihen. Ferner schwärmen die Autoren so sehr von der Auswahl von Studierenden als "Autonomie" der Hochschule, dass die wichtige, damit verbundene Frage des Ausmaßes der Stratifizierung des Hochschulsystems völlig untergeht.

Die Autoren haben eindeutig einen Hang zu einer 'forensischen' Datenpräsentation. Sie versuchen überhaupt nicht, Daten so aufzuarbeiten, dass sie eine Chance haben, die eigenen Überzeugungen in Frage zu stellen. Immer, wenn die funktionale Äquivalenz von Daten zur Diskussion stehen könnte, entscheiden sie sich vorab für eine Präsentation der Daten. Sie verzichten a priori auf die wissenschaftlich eher überzeugende Methode, auf der Basis konkurrierender Interpretationen konkurrierende Daten-Präsentationen zu bieten und somit die Daten-Sensibilität für verschiedene Vorannahmen zu prüfen. Beispiele:

- Wenn kontrovers ist, ob die höhere Stufe des Mittelbaus an der ETHZ funktional äquivalent zu den unteren Professuren von MIT ist oder nicht, so bietet es sich wissenschaftlich an, zwei Berechnungen entsprechend den beiden Positionen vorzunehmen. Die Autoren erklären jedoch vorab, dass sie der Ansicht sind, dass die wissenschaftliche Selbständigkeit für sie entscheidend ist und dass sie deshalb nur die Rechnung vornehmen, die die Annahme der funktionalen Äquivalenz verwirft.

- Wenn unklar ist, ob Doktoranden an de[m] MIT in der gleichen Weise als wissenschaftliche Mitarbeiter von Forschungsteams betrachtet werden können wie Doktoranden an der ETHZ oder nicht, entscheiden die Autoren vorab: Ja, das ist mehr oder weniger gleich.

- Wenn umstritten ist, wieweit Wissenschaftler ohne Professorenrang eine bedeutsame Betreuungsfunktion für Studierende haben, wird einfach behauptet, dass die Studenten-Professoren-Relation die einzig brauchbare ist.

- Umgekehrt, wenn an de[m] MIT eine fast doppelt so große Menge qualifizierten Personals außerhalb von Forschung und Lehre vorhanden ist, so wird lediglich die Modernität des Konzepts gelobt, ohne dies überhaupt in die sonstigen Berechnungen aufzunehmen. Wären die Autoren an dieser Stelle ihrer sonst dargebotenen Logik treu geblieben,

> hatten sie fragen müssen: Wie ändern sich Berechnungen über Betreuung bzw. relative Produktivität, wenn das Management der ETHZ entscheiden würde, x Prozent der Forschungs- und Lehre-Personalstellen in Verwaltungs-Dienstleistungs-Positionen umzuwidmen?

Auf den ersten Blick ist es äußerst sympathisch, dass die Autoren einen so hohen Anpruch an ihre Studie stellen. Sie wollen einen Daten-Friedhof vermeiden, bei dem die Leser dann nur beliebige Ranking-Diskussionen betreiben. Leider finden wir in vielen Studien zu oft, dass die Daten Differenzen illustrieren und Raum für mehr oder weniger beliebige Erklärungen gelassen wird. In diesem Falle entscheiden sich die Autoren dafür, die Morphologie von Personal-Rängen, Gruppen-Großen und Zuordnung von Organisationseinheiten in den Mittelelpunkt zu stellen und weitere Faktoren (Stratifizierung der Hochschulsysteme, Autonomie und Kontrolle, Management- und Evaluationskultur u.ä.) in die zweite Reihe zu setzen.

Beim näheren Hinsehen zeigt sich jedoch, dass die Gesamt-Anlage der Studie (Vergleich von je einer Institution in zwei Kulturen), die Daten-Aufbereitung (s.o.) und die Art des erhobenen Materials so beschaffen sind, dass sie gerade ungeeignet sind, die Stufung der Erklärungen plausibel zu begründen. Sicherlich wäre es besser gewesen, wenn auch geprüft worden wäre, ob es innerhalb einer "Kultur" bestimmte Effekte von verschiedenen morphologischen Typen gibt (hier weisen die Autoren allerdings darauf hin, dass ja manchmal die großen Institute besonders erfolgreich in der Mitteleinwerbung sind und dass dies eine saubere Prüfung der morphologischen Effekte einschränkt).

Wie wirken sich Personalstrukturen, Gruppengrössen, kooperations-fördernde und -hemmende Faktoren auf die Effektivität und Effizienz des Systems aus?

Die Studie hat im Prinzip durchaus ihre Stärke darin, dass sie eine These — die Bedeutsamkeit bestimmter morphologischer Dimensionen — in den Mittelpunkt stellt. Manche ergänzede Elemente scheinen künstlich hinzuzutreten: Offensichtlich halten die Autoren sie für wichtig, obwohl der Kern der Studie dafür nichts bietet. Zum Beispiel wird an verschiedenen Stellen behauptet, dass Qualität der Forschung und Qualitat der Lehre eng zusammenhängen. Das hätten die Autoren lieber lassen sollen, weil sie dafür weder Evidenzen bieten noch damit ihre zentralen Fragen stärken. Auch der breite Ausflug zu verschiedenen Reform-Topoi (z.B. Bologna) überzeugt nicht.

Die hier geäußerten Einwände gegenüber der Studie sind nicht in der Absicht geschrieben, den Autoren noch größere Veränderungen zu empfehlen. Die Studie ist sehr interessant, und die m.E. beobachtbaren zu große Verliebtheiten in bestimmte Wertungen finden wir in vielen Analysen dieser Art. Selbst wenn die Studie dadurch viele Möglichkeiten verschenkt, die Plausibilität des eigenen Ansatzes erfolgreich zu prüfen, bietet sie doch viel *food for thought.*

Die Stärken und Schwächen der Studie können jedoch zum Anlass genommen werden, um zu fragen: Welche Möglichkeiten bestehen — konzeptionell und pragmatisch gesehen — in zukünfigen Studien zur Wissenschafts- und Hochschulforschung ein paar Schritte weiterzukommen in der Analyse der Frage, wie Personalstrukturen, Gruppengrößen, kooperationsfördernde und -hemmende Faktoren für Kooperationen zwischen Hochschullehrern, System-Stratifizierung u.a. sich auf die Effektivität und Effizienz des Systems auswirken. Was ist erforderlich für Konzeption, Projekt-Design, Datenauswahl und nicht zuletzt an empirischen Studien, die über den Rückgriff auf vorhandene bzw. aus dem Verwaltungsprozess erstellbare Daten hinausgehen?

9.3 Swiss Commentators

9.3.1 Dietmar Braun

I read [the Report] with great pleasure and think that it presents a thorough and useful piece of work for today's reform discussions on the restructuring of universities. The study has the merit to base its conclusions on empirical indicators. I will not argue with the choice of these indicators but raise some general points that came into my mind when I read the study. I apologize for all misunderstandings and superfluous remarks that might be caused by a too quick reading of the dense chapters in the study. The remarks remain eclectic and I do not intend to present a thorough and deep-going analysis. Just take my reflections as an input for further work on this matter.

1. The comparison of two higher education institutions is certainly innovative, but are the lessons that are drawn from the comparison really something new? It very much comes down to what a large number of studies comparing the different 'cultures' have already shown. The authors are not right: there have been a number of institutional studies on this subject and in the end they quote the author — Ben-David — who [...] has developed most of the arguments that explain the differences in productivity presented in the study at hand. I also remember other studies in the 1960s in Germany when mass education became a phenomenon and the [*Deutsche Forschungs-Gesellschaft*] (DFG) as well as the *Wissenschaftsrat* published studies that recommended the American university because of its 'morphology' and institutional structures. The worth of this study for me is not its scientific contribution but the merit it has to present another discourse dimension — juxtaposed and even opposing the current new public management argument — which can induce another way to think about university reform.

2. This having said I still find that the authors lack — despite [...] their emphasis on the 'academic core', on 'learning', on 'self-organization' — a critical distance with regard to university reforms. Their main argument is that universities have to change because of a changing environment and lack of public support and that universities are just "entrenched" institutions with "vested interests" not wanting this change and therefore being doomed to fail and loose importance. In suggesting this argument the authors do not take into account the kind of change that is occurring at the moment: In many ways one can call it a 'marketization' of academic culture and scientific research. Contractualization and the privatization of knowledge as well as commercialization are characteristics of this phenomenon. Why is it not possible to see that universities might have a good reason — especially in Europe with a tradition of a 'free' and non-instrumentalized academic culture — to refuse change? In adapting to this environment, they might loose their identity important for innovation, critical thinking and the production of knowledge. The authors should never forget that they 'construct' their study and use categories that might not be shared by all participants. (Example: page 16: universities must become "service-oriented"; must "give up feudal vestiges": this is of course the kind of criticism one finds everywhere in the media). Adaptation is not a value-free notion and this should enter into the reflections of the authors. To not respond to what Max Weber once has called in another context "sterile Aufgeregtheit" of policy-making today might turn out wise in the future.

Though, if I understand it right, the authors attempt to develop an alternative point of view to university reform than the one developed in the framework of [New Public Management] (NPM) and implemented now almost everywhere, they also defend some of the arguments of the NPM. They demand for example a stronger professionalisation in universities and the abolishment of the militia-system (page 19). They should be aware that universities remain "professional organizations" in the sense of [Peter] Scott, deeply anchored in the scientific community. They cannot be transformed into enterprises. Experience shows (see for this [24]) that there are two ways until now to organize the professionalisation in Europe: either professional administrators obtain a large authority in determining university matters (the hierarchical model) or a mix between self-government and a professional administration is accepted. In the first case — take the example of the Netherlands — legitimacy problems appear and a new bureaucratization within the organization takes place. In the second case we find a good deal of immobilism. There is no perfect model until today.

My argument here is that the authors should be aware of the problem the professionalisation might cause and that it needs a very thorough and intelligent thinking how one wants to solve this problem. I find the argument offered later on that we need a "learning culture" and a "dialectic discourse" (page 101) not very helpful as it does not become clear how we could — within the power play of a large number of forces — realize such a heroic consensus among the different actors in and outside universities. This, by the way, is another criticism: the authors never use 'power' as a concept. In this, they remain very old 'institutionalists'. Without integrating power in the reflections on reform, the propositions remain abstract and idealistic.

This point demonstrates that, though the authors want to take an "insiders view" (page 26) and to strengthen the academic core instead [to] "streamline administrative operations" (page 27), they remain in the overall "logic of productivity". More productivity is both the aim of the NPM and of this study.

3. Methodologically and theoretically, I think that work still has to be done. First of all, I find it disturbing that the authors are presenting in their analysis "normative point of views" that are not thoroughly discussed but sold as common understanding. (see p. 16: "Trust and Credibility": here ideologies are simply sold; the "side-remarks" on *Fachhochschulen* — p. 98 — should be left out). There are other [such] sections in the text. While the rest of the analysis is always based on empirical indicators and analytical reasoning, the authors are selling their own personal world views here. This can be interesting but needs more discussion and reasoning.

The authors are using a causal model that could be made more explicit, for example by visualization. As I see it, the model is as such: Culture > Morphology > Output while the Input can be kept constant (no differences between the two institutions).

The authors are developing a whole set of explaining structural and institutional variables. Independent, intervening and dependent variables should be made more clear and put into a table. What is more disturbing to me is that the authors do not have a theoretical model which can explain the relationships between the variables, show if each variable as such (like student-staff ratio) explains something or only all variables together. There is no methodological tool to judge on this. Every variable is declared important, but we do not know to what degree and [...] in [what] relation [to] other variable[s]. Is there over-determination of variables, dependence of variables, et cetera? Only a very thorough causal reasoning of each factor can overcome these methodological problems. The authors should arrive at a clear causal model.

The different ways to organize hierarchies is indeed an essential point.

Without such a clear model I find it difficult to accept — only on the basis of the 'benchmark' MIT — a reform proposal like the "thinning out" of the *Mittelbau* as an adequate measure for a reform in Swiss universities (MIT has more faculty and is more productive). The value of this single factor in the whole organization and in the set of variables is not clear and it can very well be that this factor has only an important value in combination with other factors (Do not forget that, if we talk about culture as a causal factor, this might mean that we cannot at all 'copy' one variable in another cultural context but we must try to establish a comparable culture first. But I believe that the authors see this point.):

It could help to better integrate the literature as evidence. This is also a general criticism: The authors conclude on the base of two institutions, which remains a bit hazardous, though the authors are conscious of this difficulty. Only in the last chapter we find some arguments from the literature which explain very much these differences. Why not work the other way around? Present the existing knowledge of Ben-David and others and see if the two case studies fit well into the hypotheses one can develop on the basis of this literature. This would make the whole a bit stronger.

To choose similar institutions in order to learn to know about differences is — according to the literature on comparative methodology — not the first choice at hand. Clifford Geertz has demonstrated how to work with 'contrasted cases'. But in the end it becomes a bit mixed up if we are dealing here with similar or dissimilar cases. This depends on the variables chosen. The authors might nevertheless say something about this.

4. Just a few other remarks: The different ways to organize hierarchies is indeed an essential point. Mind that the American way to develop hierarchies is compatible with thoughts of NPM while the European way is not (page 30).

A good observation is that the "MIT approach" is favored by the blurring of boundaries between basic and applied research as well as other developments (Section 5.2). If one takes this argument seriously, this has considerable implications for 'lesson-drawing'. It means that MIT is just lucky because its structure created in another context are conducive for high productivity in another context. The implication is that the goodness-of-fit is just a matter of chance and that a different environment might favor other models. An example in case is precisely the Humboldt-model that has [fostered] for a long time the predominance of Germany in research at the end of the 19th century. No organizational model then has an eternal value. If this is so, we should have a clearer model of how the [embedment] of institutions today work exactly in favor of the MIT-approach and how future developments might need another model. In short, MIT might be a benchmark today, it might be Tokyo tomorrow.

Intuitively, I think that Table 7.1 is a very interesting one and needs further research.

9.3.2 Gudela Grote

[...] I found it very interesting to look at this very detailed comparison between the two universities. There are a lot of data that will help to give depth to discussions in the future where in the past very superficial accounts have been made regarding the situation at MIT especially.

It would have been interesting to describe the work process in small vs. large units and to try to derive assumptions about productivity from that.

Some of the conclusions I find somewhat short-sighted, though. The authors seem to favor the MIT model overall and use research output as [their] main argument. Regarding the research output, i.e. mainly publications and citations, language biases are discussed, but what is left out completely are biases in the process of publication and citation. The authors state at the beginning that their Report does not contain a social constructivist perspective, but particularly for the publication process this perspective would have been quite helpful. At least for the social and management sciences that I am familiar with, there is such a US dominance in the publication system that taking refereed and cited publications as the main output measure for non-US institutions is very misleading. I could imagine that in the engineering and especially in the natural sciences this bias is somewhat reduced, but I am sure it exists there as well.

Instead of trying to argue for the MIT model based on publications, it would have been more interesting to describe the work process much more in small vs. large research units and to try to derive assumptions about productivity from that. There are some elements of that in the Report, but as the authors themselves state, much more knowledge is needed. I would actually agree with the authors that small research groups further innovation better than large groups, but to take publication records as proof is somewhat misleading. I would assume that small groups and also several small groups in parallel in the same research field can provide a very good mix of competition and cooperation, with faculty being highly involved in the research and in directly research-related exchanges with other groups instead of being more political figures as is the case here. The authors mention this as well, but a closer look at what boundary conditions are needed to make this mix work would have been interesting. From what I know, having too many small groups working in parallel can also get out of hand with too much competition, especially in some of the high ranking US universities.

I do agree with the authors that looking at organizational and cultural conditions more when studying the effectiveness of universities is very useful and more studies of the kind the authors refer to would be very beneficial. Their own conclusions regarding favorable organizational forms for optimal outcomes in research and teaching should also be tempered by this lack of current knowledge, though.

9.3.3 Willi Gujer

Reading this Report it was unclear to me whom it addresses. It supports some of my gut feelings — but I did not really need the Report in order to come to very similar conclusions.

ETHZ does not have a long record of measuring research productivity — publication and citation counts have not played any (real) role in the past, when promotion, salary or resources were discussed. It will definitely take a few more years before these performance measures can be applied on equal levels with an US University (defensive I know, but relevant). Once the performance criteria are defined and enforced, it should be possible to enhance the performance of ETHZ quite rapidly (10 years). At EAWAG publication and citations became an issue in the 70s when a new director ([Werner Stumm,] a former Harvard professor) [was appointed]. The record of EAWAG has steadily improved [since].

Engineering students (and some faculty) do not have good language skills. At ETHZ even Ph.D-students may have enormous difficulties to publish in English. I guess once it is realized that research is only valuable if it is published, we can find ways to improve the publication records in some engineering disciplines of ETHZ (we could make some resources for editing available).

The student-to-faculty ratio, the staff-faculty ratio and the size of the non-academic sector should also be discussed in view of the fact that ETHZ wastes its best human resources (faculty) in a non-professional, militia management and administration system [for committees], working groups, writing reports, etc. — rather than doing research and education. This remark is in contrast with the idea of some ETHZ faculty that central administration should not obtain any more resources.

The comparison of the potential students of MIT and ETHZ is not really convincing. The motivation of the students in an US elite university is entirely different from the motivation at ETHZ. In the US it is considered to be a privilege to study at MIT, UC Berkeley, etc. In Switzerland the students have the right to study at ETHZ once they have obtained the *Maturität* (a problem of admission management!). In addition, [in the US] it is important where you obtain your science [or] engineering degree and with what qualifications. In Switzerland, in many disciplines, there is no choice of the possible university and — therefore — industry has not developed expectations to which the students must live up [to]. Furthermore, a long period of [shortages of] engineers on the market has lead to the situation where any engineer could find a job, independent of [the] performance at the university. I have graduated many environmental engineers, but so far I only had to give recommendations to employers once or twice (with the exception of those students which applied to other universities, mainly for business degrees).

Mobility of students is much [higher] in the US than in Switzerland. Who is a foreigner at ETHZ? somebody moving more than about 150 km. Compared to this standard, nearly all MIT students are foreigners.

The language problem should not be underestimated — ETHZ can only attract German speaking undergraduates (an important source of graduates). For these students, the costs of living are high in Zurich — and education is close to free at home. In addition, on the European market it is not really important from which university you obtain your degree.

Competition is considered healthy in an US University — in the European tradition competition is bad, especially among students. 1968 is still active.

The Report contains a lot of personal interpretation and judgment; one gets the idea that it should prove that the US university system is better than the European one. I would prefer a somewhat more neutral report, which will still lead to the same conclusions.

9.3.4 Hans-Jakob Lüthi

One thing in advance: The Report “MIT and ETHZ: Structures and Cultures Juxtaposed” provokes the reader. The reactions are sometimes approving, other times disapproving, and often complementary.

The methodology used in the Report is to assess and compare educational institutions based on ‘measurable’ indicators. It is assumed that this builds a coherent system for quantifying the ‘performance’ or ‘productivity’. Hence, the achievement of goals of a research university is implicitly given in this study as the frequency of publication and its citation. It is indisputable that the length of the publications list is an important factor in appointing somebody to a professorship — both in Europe as well as in America. But it is not at all a key success factor since ‘length’ is not an appropriate measure for the importance [or] quality of research. The frequency of citation is somewhat better in this sense, but even this indicator suffers under the “publish-or-perish syndrome”. The authors were aware of these shortcomings, especially regarding the (weak) statistical sample size and its short time frame.

Both MIT and ETHZ have hardly achieved their worldwide recognition through the sum of their publications, but rather through their original and enduring impact in many important research areas coupled with excellent teachings. In my opinion, the quality of an institution has to be measured by its ability to attract the 'best' researchers. I agree with the authors that MIT offers young scientists an excellent environment for research and teaching, thanks to its (current) flexible organization. However, I would have liked to learn more about the structural differences between the management systems of the two universities. As an example, the superb tutorial support of students at MIT is the result of the 'customer-oriented' management philosophy that is typical for American universities. Likewise, the undoubtedly higher publication rate of American colleagues (not only at MIT!) can be directly attributed to an institutional incentive: American universities expect an adequate amount of publications for their fund raising, since otherwise the funding would cease. In addition, these external funds are part of the wage, thus the researcher is rewarded directly for his success. In Europe, the 'independence' of research is valued highly and, therefore, such a gratification system is disliked, with observable consequences!

In the study, the different philosophy on research and education of the two institutions (cultures) are in my opinion not considered deeply enough. There is a provocative reference to Humboldt's principle of a professorship applied in Europe. However, I miss a convincing critical analysis of the American service and customer-focused 'educational market system' that could explain partially the observed flexibility and adaptability of American educational institutions. Furthermore, given these differences in the (perceived) missions, those differences are reflected in the corresponding management systems! Again, my statements above are made in general terms, [...] for American versus European universities and not as for ETHZ versus MIT.

The superb tutorial support for students at MIT is the result of the 'customer-oriented' management philosophy that is typical for American universities.

Several interesting thoughts are raised by reading this study. Some of them are:

- The proposal to measure ETHZ by 'benchmarking' it with other universities — among others MIT — has to be adopted. Yet, this comparison based on bibliometric measures needs to be accompanied by other internally available data that can better characterize the productivity and quality of the output (in both teaching and research!). In particular, the attractiveness of the university (or its departments) could be measured by the assessed quality of the applicants for open positions.

- The anticipated inferior performance of ETHZ compared to MIT according to bibliometric data has to be verified through random tests which must be accompanied by further comparisons with other American and European universities over a much longer time period. This would give additional insights on structural and cultural differences [or] similarities of diverse institutions.

- The obvious structural differences of the two institutions can be explained by their philosophies, i.e. the European principle of (single)

Lehrstuhl versus the American system of 'educational competition'. This fundamental (self-) conception is the starting point for initiating adaptations and improvements as well as for planning greater coherent interventions on various levels.

- The methods of leadership, management, and incentive of the two universities have to be further investigated heeding special notice to their cultural environment. In particular, two questions must be considered: "Which system has a greater variability and adaptability?" and "Is this achieved at the expense of 'less continuity' in research?"
- The Bologna process is an excellent opportunity for initiating fundamental structural reforms and accelerating organizational change. The management of such a process for change can no longer be based on the popular volunteer system (*Milizsystem*) but needs professional leaders competent in coping with the natural "resistance to change" of (university) systems. Else, there is the risk that — due to scarce human resources, lack of competence and time pressure — the faculty lacks the strength or motivation for a fundamental structural change.

Let me finish by thanking the authors for their inspiring, interesting, and also courageous ideas that provided me with many insights for a better understanding of institutional 'performance'. It is my hope that the responsible management instances do not disregard this study. Instead, the raised thoughts have to be pursued, deepened and appropriate action must be taken.

9.3.5 Eva Krug

The Report asks how one can measure the effectiveness and productivity of higher education. The authors specifically consider how ETHZ compares to MIT (benchmark) in terms of admissions, student-faculty ratios, programmes offered, drop-out rates and financial autonomy.

The findings are clearly reported. My input comes from an overview of the document, complemented by observations during my post-doctoral research at MIT and membership of the "Board of the MIT Club of Switzerland" (1993 to present). The key messages for reforming ETHZ follow from:

Student Admissions MIT is a private (non-profit) institution that selects its students (high tuition fees). ETHZ is a public institution with an open admission policy (low tuition fees). Both institutions are committed towards undergraduate education and research.

Academic Programmes MIT has a broader base: natural sciences, engineering, humanities and social sciences, and architecture — and a prestigious management school. MIT is unique in offering interdisciplinary degrees (e.g. engineering plus biology). Also students with a technical background can learn management skills on campus. All undergraduates at MIT follow an obligatory 'Introduction to Biology' course and a language (i.e. attempt to offer more balanced education).

Student-Faculty Ratio [...] The more favorable student-faculty ratio fosters more frequent and more informal interactions. As faculty at MIT is encouraged to consult (I think 20% of their time), students are exposed to a research and entrepreneurial culture. Undergraduates at MIT become engaged in a research project as an integral part of their studies. The lower number of faculty may explain the much higher drop-out rate among freshman at ETHZ [...]. This difference may reflect that ETHZ students only undergo a selection process after the examinations at the end of year 1 of studies, whereas at MIT a rigorous selection is applied at the admission phase.

Change Management MIT puts its future in its own hands. It relies on its own resources to consider and implement change management. MIT itself took the initiative to reinvent MIT education [145, 144, 143] with a view to eradicate barriers between disciplines, students and faculty, the social and academic. The MIT philosophy on shaping the future resulted in the decision (April 2001) to make course materials freely available on World Wide Web for non-commercial use (MIT OpenCourseWare), reflecting the MIT commitment to disseminate knowledge across the globe.

Funding Base MIT responded to the erosion of government defence contracts by broadening its funding base to outside resources from industry and foundations. It also generates income via the MIT Technology Licensing Office and smart investment of its endowments (recently to include real estate). ETHZ is much more dependent on federal funds.

The MIT Alumni Association is very active and not just in Cambridge, USA and undertakes extensive fund raising activities.

9.3.6 Jean-Philippe Leresche et Juan-Francisco Perellon

Nous aimerions d'abord exprimer tout le plaisir et l'intérêt pris à la lecture de ce document très riche et passionnant. De notre côté, nous n'avons pas d'expertise particulière sur le système américain d'enseignement supérieur, c'est pourquoi nous ne ferons ici qu'un commentaire succinct qui n'est probablement pas destiné à améliorer le rapport mais à y réagir essentiellement positivement.

Commençons donc par saluer la grande cohérence, l'intérêt et la qualité du document dans ce qu'il a d'informé et de détaillé. Il apporte un éclairage pertinent sur des réalités fort différentes. Ces diverses réalités font que, parfois, les juxtapositions/comparaisons sont difficiles à réaliser pleinement, mais ceci est reconnu par les auteurs eux-mêmes. Aussi, tenons-nous à féliciter les auteurs pour les propositions/réflexions qu'ils formulent sur le cas suisse dans quelques passages du document. Relevons en particulier les propositions/réflexions relatives à la transformation de la situation du corps intermédiaire.

Les lignes qui suivent ne sont que quelques commentaires généraux qui n'enlèvent rien à la qualité du document.

La notion de 'morphology' Les auteurs notent qu'ils empruntent cette notion à Bourdieu et que ce dernier n'en donne pas une définition explicite. D'accord sur ce point. Cependant, il nous semble que l'on devrait éviter le piège sémantique quand on se réfère à la notion de *faculty*. Le texte l'adopte dans son acception nord-américaine (i.e. professorat 'stabilisé' et 'autonome' — par opposition à *staff*) et toute la discussion sur les transformations des ratios étudiants-professorat et *staff*-professorat, qui sont la base de la réflexion de Bourdieu, est faite en conséquence. Cependant, Bourdieu parle de transformations des Facultés (en tant qu'unités de recherche et d'enseignement) et non pas de professorat. Une petite note rappelant la différence serait la bienvenue, à notre avis.

La notion de 'culture' La notion de *culture* est au centre du document. Malheureusement, elle ne semble pas être l'objet d'une attention conceptuelle approfondie. Ceci est dommage et laisse le lecteur dans le flou quant il s'agit de déterminer de quoi l'on parle effectivement quand l'on utilise le concept de *culture*. La cohérence du texte en sortirait grandie, si les auteurs mettaient en avant leur point de vue sur la question et étaient plus explicites sur l'usage qu'ils en font.

Le terme *culture* est utilisé de manière variable, pour faire généralement référence, semble-t-il, à l'architecture organisationnelle des deux institutions. Dans cette acception, on a affaire à la 'culture institutionnelle', ce qui est en ligne avec l'approche générale adoptée par le document (sociologie et *institutional research*). Cependant, lorsque l'on traite de questions comme la productivité et l'efficience, il nous semble que l'unique entrée par la dimension institutionnelle est trop limitative. Dans une certaine mesure, il serait intéressant de l'aborder sous l'angle de la 'culture académique', approche davantage centrée sur les individus et l'impact que les changements structurels décrits au chapitre 8 (première partie surtout mais également, de manière sous-jacente, dans les chapitres traitant de l'importance prise par les questions liées à l'efficience) ont sur le *staff* et la *faculty* qui "produit la recherche scientifique".

De même, la question de la 'culture académique' est également présente lorsque l'on aborde, au chapitre 8, la question de la possibilité de changement institutionnel et de la façon dont les membres qui composent les facultés (au sens francais) agissent [8.3][4].

La question des 'processes' Le chapitre 7 vise à analyser "to what extent output [...] differentials are attributable to differences of what we have subsumed under the headings of processes [i.e. the transformation of inputs into outputs] or morphology".

Il nous semble cependant que le document, principalement le chapitre 4 qui traite la question de manière directe, n'est pas très explicite sur la façon dont les processus sont effectivement réalisés. La transformation de l'*input* en *output* (présentée par les auteurs comme la définition-même du 'processus') est, on peut le supposer, variée et non-unilatérale.

[4] Jean-Philippe Leresche and Juan-Francisco Pelleron suggest the following "références intéréssantes sur la notion de culture académique": [97, 119, 120, 122, 136, 225].

Il est légitime, par exemple, de porter son attention sur l'utilisation des ressources mais il serait tout aussi important également de s'intéresser aux méthodologies pédagogiques qui sont utilisées dans les deux institutions et qui sont en première ligne quant il s'agit d'aborder des questions comme le taux d'abandon ou la durée des études (questions abordées au chapitre 4).

Ce qui est analysé, ce ne sont pas des processus mais des photographies de situations données (les ratios sont les meilleurs exemples pour cela), des snapshots, pris à des moments particuliers. Le passage d'un moment à l'autre au fil du temps, i.e. le processus, demeure une *black box*. Or, c'est dans l'analyse de cette *black box*, surtout en ce qui concerne la question des étudiants, que la comparaison aurait été fructueuse, parce qu'elle aurait permis de mettre en évidence, ou non, des cultures et des méthodologies pédagogiques différentes entre les deux institutions (différences renvoyant elles-mêmes à des niveaux supra-institutionnels).

Nous comprenons bien que ce n'était pas l'objet premier du rapport de centrer l'attention sur des questions relatives à la manière dont les *inputs* sont effectivement traités au sein des institutions. Cependant, il semble quand même important de noter que, par conséquent, ce ne sont pas véritablement des 'processus' qui sont analysés dans le document (chapitre 4 principalement).

Institutions within a context L'on peut se demander pour quelle raison ce chapitre est placé en fin de document. Il pourrait faire une excellente introduction générale à la problématique traitée. Pourquoi ne pas le mettre en début de texte?

9.3.7 Werner Oechslin

Ich habe mich aus Zeitgründen an [die] "Leseempfehlungen" gehalten und mich bei der Lektüre insbesondere auf die einleitenden und zusammenfassenden Kapitel beschränkt. Dementsprechend werde ich weniger auf Einzelheiten eingehen, so sehr es in mancher Hinsicht gerade darauf ankommt (!), um stattdessen 'im Blick aufs Ganze' wenige Überlegungen beizusteuern.

Zum besseren Verständnis füge ich hinzu, dass ich seit 1985 an der ETHZ tätig bin und andererseits 1975 und 1978 jeweils ein Semester als Gastdozent respektive Gastprofessor am MIT unterrichtete, somit über eine 'gewisse' innere Kenntnis auch des MIT verfüge. Da die vorgelegte Analyse nicht nur von *structures*, sondern eben auch von *cultures* handelt, ist dies wohl in besonderer Weise relevant.

Kultur Ich setze deshalb gerade an den Beginn entsprechende 'kulturelle' Reminiszenzen, um an einem meines Erachtens zentralen Punkt mit der Argumentation zu beginnen und dabei vorwegzunehmen: gerade für 'Spitzen-Hochschulen' gilt, dass eine quantitativ-statistische Erfassung vielleicht vieles beschreibt, aber wohl kaum den Kern der Sache trifft. Es sind überragende Persönlichkeiten, die eine überragende Hochschule als überragend kenntlich machen. Und dies lässt sich nicht zergliedern in Teilquantitäten oder Teilaspekte. Individuelle Merkmale — und sie sind bei 'exzellenten

Persönlichkeiten' häufig besonders ausgeprägt vorhanden — entziehen sich mehr als andere vergleichenden, statistischen Formen der Beurteilung. Und dies lässt sich weder umgehen, noch ersetzen.

Also folgen hier konsequenterweise vorerst 'Beispiele' (im Sinne der einst als kategorie-tauglich befundenen *exempla*): Am MIT habe ich während eines Semesters Tür an Tür mit Kevin Lynch gearbeitet, ihn übrigens kaum je gesehen, einmal ein längeres freundliches Gespräch geführt. Er ist innerhalb der gegebenen Strukturen am MIT kaum in Erscheinung getreten … , ganz offensichtlich, um möglichst ungestört und effektiv forschen zu können. Nach aussen war unbestritten, dass er, weltweit anerkannt, als eine führende Persönlichkeit in seinem Gebiete galt. Er genoss deshalb innerhalb des MIT optimale Bedingungen: im Rücken eine renommierte Hochschule, für die eigene Arbeit die grösstmögliche Freiheit, die er sich umgekehrt durch seine internationale Anerkennung einhandelte.

Am MIT begegnete ich auch (noch) Roman Jakobson, der dort lange nach seiner Emeritierung [1967, an der Harvard University] ein — wenn auch sehr kleines — Büro benützte. Die ganze Welt kennt Roman Jakobson. Man konnte zudem auch wissen, dass man ihn am MIT finden würde, das dafür besorgt war. Am MIT agierte damals [Noam] Chomsky — am Höhepunkt seiner politischen Tätigkeit angelangt — gegen die Proliferationsabsichten der USA zugunsten des Iran in Sachen Nukleartechnik, was belegt, dass am MIT auch solche Probleme ohne nennenswerte Störungen ("man ist stark genug") kontrovers diskutiert werden konnten: sollte denn jemand (frei) entscheiden, dass dies wissenschaftsrelevant sei … (Chomsky tat es!) Und so fort … Fazit: Unabhängig davon,

- ob einer seine Forschungsleistung im engen Team optimiert und das MIT in erster Linie als 'Schutzschild' und 'Renommieradresse' benützt (um ihm dann, dem MIT, handkehrum wiederum etwas an jenes kollektive Renommee abzutreten!),
- ob einer seine Affiliation, obwohl selbst längst ein eigenständiges Monument der Wissenschaftsgeschichte, zum MIT behält und insofern ebenfalls in beide Richtungen 'wirkt', oder schliesslich
- ob einer seinen eigenen (durchaus 'kontroversen') Gang in die Öffentlichkeit am MIT ansiedelt, um auch hier Autorität und Prestige — nutzend wie neu schaffend — selbstbewusst einzusetzen,

stets ist es der Zusammenhang MIT und hochrangige Forscherpersönlichkeit (früher hätte man auch gesagt: 'Wissenschaftler' oder gar: 'Intellektueller'), der diese ganz besondere Qualität umschreibt. (Natürlich [bin ich] der Meinung, dass die ETHZ — insbesondere bezogen auf das besondere helvetische Umfeld — das entsprechende Potential, das durchaus (und immer noch) gegeben ist, eher schlecht als gut nutzt, was für das oben vorausgesetzte Selbstwertgefühl einer (und an einer) Institution jedoch sehr wichtig ist.)

Nun ist der vorliegende Bericht weit mehr als ein blosses Zahlenwerk und verdient deshalb besondere Anerkennung und sorgfältigste Aufmerksamkeit. Allein, man kann nicht genug die Priorität herausheben und betonen: 'Forschung/Qualität/Bedeutung' geht von den Persönlichkeiten aus. Und die Qualität einer Hochschule muss sich nach wie vor in erster Linie daran messen lassen, ob es [der Hochschule] gelingt, solche Persönlichkeiten zu gewinnen, um sie dann 'vorweisen' zu können; und folgerichtig, ob sie in der Lage ist, deren Situation förderungswirksam, 'attraktiv' zu gestalten, eine Bühne zu bieten, etc. Betrachtet man die Dinge aus dieser Sicht, wird man schnell erkennen, dass die gegebenen (und natürlich unvermeidbaren) 'Strukturen' so oder so stets riskieren, mehr behindernd als befördernd in Erscheinung zu treten.

Die meines Erachtens zentrale Frage des *change management* (vgl. Kapitel 1, p. 19; Section 7.3) ist wohl der sensible Ort, an dem solches mitbedacht werden kann und muss. (Nicht überraschend für mich, schneidet hier das MIT in der Bewertung deutlich besser ab und wird die ETHZ sanft aber deutlich kritisiert.) Diese Strukturen werden im Bericht völlig korrekt und angenehm provokativ als "Kulturen" beschrieben. Es müsste folgen: man muss konsequent an diesen Kulturen arbeiten (von der positiven Wahrnehmung zu deren pro-aktiven Bearbeitung). Allerdings erscheinen mir die Thesen zu *cultural differences* und/als *mismatch* (siehe: Kapitel 1, Seite 15) irritierend und [bzw.] oder nicht zu Ende gedacht. Dazu die kritische Bemerkung: die ETHZ ist dabei — notabene mit der gewonnenen Autonomie — gerade das zu verspielen, was das MIT erfolgreich zu seiner eigenen Kultur gemacht hat, nämlich eine 'nationale' (natürlich kulturell und nicht politisch aufgefasst!) Institution auf überzeugende Weise darzustellen.

> *Ich bin der Meinung, dass die ETHZ — bezogen auf das besondere helvetische Umfeld — das entsprechende Potential, das durchaus (und immer noch) gegeben ist, eher schlecht als gut nutzt.*

Eine solche überragende Bedeutung richtet sich nicht nach der Massgabe erfüllter, von aussen herangetragener Erwartungen, sondern nach der 'erwarteten' Wahrnehmung und Behauptung einer eigenen wissenschaftlichen und kulturellen (= Relevanz/Folgen bedenkenden) Kompetenz. Hier macht sich — und das ist 'kulturell' bedeutsam — der Kontrast von *de facto*-kurzfristigen Entscheidunsgsräumen (in Politik, Wirtschaft, …) und mittel- und langfristiger Denk- und Vorstellungswelten (sic!) der Wissenschaft, die notabene nur unter dem Aspekt der (akademischen) Freiheit einzuhandeln sind, bemerkbar. In diesem Zusammenhang sind keinerlei "chauvinistische" Vorurteile (Seite 6) zu fürchten (wenn schon, ist das eben Teil der 'Kultur'); aber es sollte auch nicht — unter dem Titel von 'kulturellen Unterschieden' — die Rede von mangelnder Anpassung an die äusseren Umstände von Gesellschaft und Wirtschaft sein, ohne dass dies als (kulturelles) 'Vorurteil' bezeichnet wird. (Andernorts, in Kapitel 8, steht man doch dazu, dass (nur) radikales, also vorurteilsfreies Fragen am Anfang stehen müsse.) Anpassung riecht nach 'subsidiärer', nachgeordneter Form der Wahrnehmung 'gesellschaftlicher Relevanz', wo doch ganz im Gegenteil die selbstbewusste Wahrnehmung der eigenen Kompetenz in letztlich gesellschaftlichen Fragen gefragt sein müsste: 'vorgängig' und deshalb weitgehend unabhängig von äusseren Sachzwängen.

Exkurs Es ist ein verhängnisvoller Irrtum zu glauben, gesellschaftliche Relevanz ergäbe sich (nur) auf das pünktliche und möglichst schnelle (hier gedenke man Achilles' und der Schildkröte!) Eingehen auf bestehende gesellschaftliche Probleme: auf diese Weise wird man stets hinterhereilen, dienend, ausübend … und dann überschlagen sich die Ansprüche und Forderungen an die Adresse einer "anwendungsorientierten, praxisnahen Forschung" … Eine Wissenschaft ist dann exzellent, wenn sie vorab Probleme zu erkennen vermag, heisst: lange bevor sie 'allgemein' wahrgenommen und allenfalls gesellschaftlich 'wirksam' werden. Der 'gute Intellektuelle' war einmal der Rufer in der Wüste, dessen Einschätzungen, Prognosen, Erkenntnisse kaum geteilt, überhört wurden … und dann vielleicht später doch noch begriffen wurden.

Eine Wissenschaft ist dann exzellent, wenn sie vorab Probleme zu erkennen mag, lange bevor sie allgemein wahrgenommen und allenfalls gesellschaftlich wirksam werden.

Deshalb, so die Versuchsanordnung, bedarf es des Schutzschildes einer Institution, die in solchen Fällen eine ausreichende 'Anfangsautorität' leihen kann! Wenn das Schleiermachersche Motto ("Vom Gefühl des Mangelnden gehen alle Verbesserungen aus", Seite 1) Sinn machen soll, so muss man gerade dies immer wieder betonen. Die Hochschule kann und darf nicht die äussere Welt, die sich häufig genug auf kausale oder pseudokausale Zusammenhänge verlassen will (Politiker argumentieren weitestgehend auf diese Weise), abbilden, sondern muss anders, 'spezifisch' Denkfabrik sein.

Morphologe und anderes Es ist wohl allzu deutlich: [ich komme] immer wieder auf die zentrale Frage der Bedeutung einzelner, exzellenter Persönlichkeiten zurück und versuch zu betonen, dass der ganze Ballast von Fragen nach Organisation, Verfahren, Strukturen, etc., dem nachzuordnen sei. Tut man dies, bringt dies übrigens Vorteile mit sich, dass man letztlich weniger verbissen, dies oder jenes (zum Beispiel 'Bologna') beurteilt und 'anwendet'. Trotzdem: Es ist natürlich nützlich und angebracht, institutionelle Vergleiche zu verfeinern, wie das angeregt wird, um einzelne Sachfragen möglichst präzis, konkret — letztlich eben wieder massgeschneidert und 'individuell' — zu erfassen. Es überrascht nicht, wenn man liest, dass [der Studenten-Professoren-Quotient] am MIT viel besser ist und folgerichtig Forschungsgruppen dort kleiner (und effizienter) sind. Das allerdings ist — mit Blick auf Hochschulpolitik europaweit — ein Politikum erster Güte. (Man hat z.B. in Deutschland insbesondere die Geisteswissenschaften auf diese Weise zugrundegerichtet!) Es scheint mir in jedem Falle richtig, den Blick auf die Fragen der 'Morphologie' zu schärfen. Die Vermutung, es bestünde ein Zusammenhang von Leistungsdifferenz und 'Morphologie', ist mehr als berechtigt. (Im übrigen habe ich konsterniert Kenntnis davon genommen, dass die *institutional research* es bisher verpasst hätte, hinlänglich auf Effektivität und Produktivität im Wissenschaftsbetrieb zu achten (siehe: Foreword, Seite 5).

Diese Überlegungen mögen als zufällig, ungenügend fokusiert, allgemein und länglich gehalten erscheinen. Mir scheint aber gerade dies die adäquate Form einer Reaktion zu sein, um das, was im Bericht zuweilen mit 'vagen', dafür aber komplexitäts-freundlichen Begriffen wie 'Kultur' oder auch 'Morphologie' (mit oder ohne Bourdieu) beschrieben wird, nicht gleich wieder dem Statistiker und seinem Zahlenwerk zu überlassen. Die Analysen, Beobachtungen müssen an entscheidenden Stellen verfeinert und das Ganze ins Grundsätzliche weitergedacht werden.

9.3.8 Sotiris Pratsinis

This is a nice document with a wealth of data and information. The authors of the Report should be congratulated for their thorough and in depth analysis.

From my 20 year experience in US universities one may address also two items:

1. MIT has a better chance than ETHZ to recruit and retain top researchers from non-European countries as it is placed in a society more diverse than the Swiss. Given the world population, this is not trivial when it comes to who has the best people in the world. I believe this is obvious and should be stated even though one could compare the ethnic distribution of faculty, researchers and students between the two schools.

2. MIT and US universities, in general, utilize more effectively the Annual Faculty Reports than ETHZ to provide performance feedback to the faculty and determine promotions, annual salary raises, seed research funds and space to name a few of the contentious academic issues. I believe it may be worth to include as an appendix the one-page ETHZ annual performance report summary and that of MIT if available. Furthermore, it may be worth to state how various administration levels at ETHZ and MIT utilize these reports today.

Another issue may be the applicant pools for faculty. These data may be easy to obtain for MIT and ETHZ especially for Assistant and Associate Professor. One may like to see how many people apply for these positions to each school. This may be quite interesting also for Ph.D-students although ETHZ does not utilize a central admission procedure to compare transcripts of applicants, but including these data from MIT can provide a future yardstick for ETHZ.

9.3.9 Daniel Spreng

Ich habe den Bericht mit Interesse gelesen und fand viel Interessantes darin. Die folgenden Bemerkung sind als Ergänzung gedacht.

Die Idee, Vergleiche dieser Art durchzuführen, finde ich spannend und ich möchte den Autoren, die offenbar auch die Initianten sind, dazu gratulieren. Betrachtet man die beiden Institutionen als System, scheint mir notwendig, das Umfeld (USA und CH) stärker mit in die Analyse einzubeziehen und die *Inputs* und *Outputs* etwas differenzierter zu betrachten. Hier einige weiter auszuführende Hinweise:

- *'Human' Input:* Das MIT ist die beste technische Hochschule in einem Land mit vielen technischen Hochschulen und kann deshalb seine Studenten aus einem viel grösseren *pool* auswählen. Ähnliches gilt tendenziell für die Professoren, obwohl die ETHZ grosse Anstrengungen macht, und es sich viel kosten lässt, Professoren auch von weiter weg zu rekrutieren. Bei den Studenten hat die ETHZ den Vorteil, mit Studenten 'versorgt' zu werden, welche eine bessere Mittelschule besucht haben als die *freshmen* am MIT.

- *Monetary Input:* Die ETHZ kriegt mehr Geld, das für *curiosity driven research* eingesetzt werden kann. Dies ist für die Richtung der durch die Forschung induzierten Entwicklung der Gesellschaft ein grosser Vorteil. Das tiefe Schulgeld an der ETHZ hat grosse soziale Vorteile, kann aber mit ein Grund dafür sein, dass Studenten einzeln oft als *quantité négligable* behandelt werden. Allerdings darf hier auch vermerkt werden, dass die ETHZ i.a. bessere (weniger flexible) Studienpläne anbietet.

- *Wettbewerbssituation:* Die ETHZ ist in der Schweiz praktisch unumstritten; zudem herrscht in der Schweiz eine Kultur des *understatements.*

- *Sprache:* An der ETHZ wird noch viel auf Deutsch publiziert. Dies müsste wohl bei der 'Messung' des *Outputs* berücksichtigt werden.

Die Empfehlungen, scheint mir, müssen unter Berücksichtigung dieser und allenfalls weiterer Umfelddifferenzen erfolgen. Verheerend wäre, Vorteile, die die ETH Zürich heute hat (humanistische Tradition; Bearbeitung breiter, grundlegender Forschungsfragen) aufzugeben, um den offensichtlichen Vorsprung, den das MIT in vielerlei Hinsicht hat, einzuholen.

9.3.10 Kurt Wüthrich

[The authors] entertain the idea that the 'Harvard System' for the hiring of faculty can be used to achieve high visibility, possibly also in a new field and in a rather short time period. To this I would […] add that leading research organizations in the USA, including MIT, contribute to maintaining high visibility by exploiting the potentialities of working without mandatory retirement age. The faculty in the age bracket that would in our system be forced into retirement has a particularly important role also in fund raising among alumni and similar.

The high success rate of students at private US Universities is largely a consequence of the stiff competition for the best students. The success rate is clearly an important factor in the decision-making on where to apply.

[The authors] write that the size of the research groups in the US is small compared to the group size at the ETHZ. As far as my observations go, there are plenty of opportunities for work with extremely large research groups in US Universities. The key difference is that the funding has to come from outside sources. A principal investigator with a large group will thus contribute to the financing of the University with the overhead on his grants. On the other hand, principal investigators with little or no research activities will not automatically be provided with a sizeable outfit through institutional funds. In my opinion the US system has the advantage of catering more flexibly to the needs and ambitions of the individual principal investigators. The advantage of the ETHZ system is to be seen primarily in the (rather rare) cases where long-term projects are pursued, which might have to be abandoned for lack of funding in the US system.

Chapter 10

Rejoinder by the Authors

We need continual but informal democratic explorations on the part of the people who must thread their ways through governmental, business, or volunteer and grass-roots policies, or must wrestle with the moral conflicts and ethical puzzles that sprout up unbidden in all manner of occupations.

Jane Jacobs [107]

The commentaries and critical analyses we received open up a wide spectrum of issues. Some refer to the central focus of the present study, the relation between productivity and morphology of research universities, and some reach beyond this primary focus and touch on issues which we have covered in passing or not really referred to at all. We cannot respond to all the commentaries we received, but we shall try to answer some of the more central questions raised. It is clear that if we were to write the Report now, with all the constructive suggestions we have received in the meantime, we would perhaps place different emphases and would include aspects which are missing now or exclude material we thought in the process of research to be more central.

The broad spectrum of inter-related issues referred to in the commentaries points to the fact that research on higher education is multi-faceted and complex. Many issues appear under-researched, particularly in the continental European context, and particularly as far as comparative analyses are concerned[1]. In the construction business one practices a 'logarithmic' approach to investment: it is customary to invest roughly 10% of total investment for specific project analysis and design, and 10% of this again — i.e. 1% of total investment — for exploratory analysis and planning. This 1% of total investment is a good investment: it helps to prevent physical structures which do not serve their purposes well. Well-planned structures or structural complexes are easier to design and cheaper to build, and the investments which flow into exploration and planning are easily recuperated

[1]After the completion of the present Report, a new benchmarking study came to our attention [18] which covers ten research universities, among them MIT and ETHZ.

later on during the processes of implementation and usage. If we apply this logic to higher education and look at the total investment which flows into this sector in Switzerland, for instance, we could finance roughly 400 person-years per annum in research on higher education (and related planning activities). We doubt that current expenditures in this sector reach that level.

10.1 The Production-Morphology Nexus

Our Report focuses on the link between production and morphology in research universities, in spite of the fact that other — not necessarily independent — productivity factors are involved: leadership, entrepreneurship, motivation of students and faculty, incentive systems, mentoring, et cetera. As we have pointed out in the Foreword (page 3), our interest in comparative analysis of institutions of higher education dates back to the early 1990s. The interest was fueled by reports such as [239], issued by various agencies (OECD, SWR, etc.), which appeared to overstate the contributions of small nations vis-à-vis a quasi-continent such as the US. While these reports must have been studied by hundreds of social scientists, policy makers and politicians, we are not aware of any critical analysis of the practice to directly compare small nations (such as Luxembourg) and large entities (such as the US)[2]. Because our intuition told us that it would be more appropriate to compare Switzerland with the State of Massachusetts, for instance, or Swiss universities with peer institutions within the US, and because CEST shared this view and embarked on institutional analyses, CEST commissioned — as a first step — a study which would try to juxtapose these two leading technical Institutes of Technology. The idea was to see whether we could identify possible factors which might play a role in explaining the output differences CEST detected, factors which could be studied in greater depth later on. In this particular context we were focusing on the production-morphology nexus.

Productivity Assessment Productivity is not easy to assess. One needs output measures which find acceptance and which are accessible, and the commentaries received attest to the fact that not all are happy with bibliometric indicators or research prizes as primary output measures of a research university: language biases may distort the outcome, or research measures may not fit the educational function of a university. Furthermore, output measures ought to be indicative of the institutional mission pursued, and here MIT (with a quasi-continental role) and ETHZ (with a more domestic focus) may differ and bibliometric measures or Nobel prizes clearly will not tell the whole story. Furthermore, one needs corresponding input measures, i.e. input measures which could be directly tied to the output measures chosen. For practical reasons, we concentrated on head-counts as the primary

[2] We are not claiming that such critical analyses do not exist. We are saying we should have stumbled over them in the course of our work without searching for them specifically; or we should have found some remarks in the reports themselves which would critically assess this practice.

input measure (and not on financial data as MICHAEL SHATTOCK and others would have liked or preferred), but these head-counts were not directly tied to the output measures under discussion: we just did not have access to such data. Bibliometric output measures referred to journal classes, for instance, and input measures to departmental associations (but the necessary 1–1 correspondence to tie output to input was lacking).

There appears to exist a performance gradient which separates US research universities from those of the rest of the world.

Under these circumstances, should we have avoided embarking on this comparison? We don't think so. We wanted to focus attention on productivity issues which we feel are present, and while we were unable to measure productivity properly, we tried to assemble data on the base of which productivity differences appear plausible. Once this plausibility receives credence, further research might focus more properly on whether productivity differences in fact exist and might shed light on the systemic or cultural aspects which 'cause' these differences. The newly published data by CEST attest to the fact that output differences exist, provided we accept bibliometric indicators as output measures. CEST focused on five bibliometric indicators (pertaining to data within the time-span of 1994-99), four of which we shall briefly discuss here [54]: volume of publication, volume of high impact publications, percentage of high impact publications, and mean impact of publications. For each of these four bibliometric indicators, CEST identified the 50 higher education institutions (world-wide) with the highest respective scores. If we look at the geographic distribution of these institutions, we obtain the following picture:

- *Volume of Publications:* Among the 50 research universities with the highest publication volume, we find 30 US institutions and 20 institutions which are situated elsewhere: 5 in Japan, 3 each in Canada and the UK, 2 each in Italy and Sweden, and one each in Belgium, Finland, France, the Netherlands, and Spain.

- *Volume of High Impact Publications:* Among the 50 research universities with the highest numbers of high impact publications, we find 6 non-US institutions: the Universities of London (Rank 2), Cambridge (Rank 11) and Oxford (Rank 22), University of Toronto (Rank 25), the Swiss Federal Institute of Technology in Zürich (Rank 41), and the McMaster University in Hamilton, Canada (Rank 49).

- *Percentages of High Impact Publications:* Among the 50 research universities with the highest share of high impact publications, we find 5 non-US institutions: the University of Cambridge (Rank 14), the Swiss Federal Institute of Technology in Zürich (Rank 28), Oxford University (Rank 29), the Swiss Federal Institute of Technology in Lausanne (Rank 38), and the McMaster University (Rank 39).

- *Mean Impact of Publications:* Among the 50 higher education institutions with the highest mean impact, we find 11 non-US institutions: the

> University of Winnipeg, Canada (Rank 2), Högskolan i Jönköing, Sweden (Rank 7), University of North London, UK (Rank 16), Bournemouth University, UK (Rank 20), University of Lethbridge, Canada (Rank 23), St. Francis Xavier University in Antigonish, Canada (Rank 25), Gesamthochschule Kassel, Germany (Rank 38), University of Cambridge, UK (Rank 43), Nagoaka University of Technology, Japan (Rank 45), Universität Mannheim, Germany (Rank 49), and University of Oxford, UK (Rank 50).

To us, these results indicate that it appears plausible to assume that the differences in bibliometric measures are at least partially caused by differences in higher education 'cultures' — which in turn appear to affect productivity. There appears to exist a performance gradient which separates US research universities from those of the rest of the world.

Output and Input Indicators We have mentioned before that some commentators were not particularly pleased with our choice of indicators. The bibliometric output measures chosen where criticized as being biased, because they would underreport publications in particular fields or languages, or not indicative of the real accomplishments and mission of an engineering school. Other measures were proposed, outcome-measures, some of which are much more difficult to collect, some can be expected to correlate with bibliometric output measures, and some may be practically meaningless in the present Swiss context, as the remark of Willi Gujer attests to when he observes that "any engineer could find a job, independent of performance at the university". We are not negating the biases or limitations of bibliometric output measures. In fact, the new data of CEST [54] cited above appears to indicate a significant under-reception of Japanese research, for instance. But we argue that bibliometric measures are valuable tools to assess research output, particularly when we find large output differences (as was the case in our study). And when we look at the production-morphology nexus — and look at the role of doctoral and post-doctoral students in this particular connex — we conclude that bibliometric measures can be seen to be indicative of educational matters as well.

The real bottleneck is that, in certain fields, not enough faculty are employed.

While the output-side of the process model chosen was represented by some straightforward indicators, our choice of input indicators had by necessity a much more 'softer', qualitative touch: it is not that easy to assess, in a comparative context, quality of faculty, staff and students. Our rough attempt to assess the cognitive abilities of Swiss 'freshmen', for instance, was not seen as being "really convincing" by Gujer because motivational factors were not included, while Daniel Spreng sees an advantage of ETHZ to have students "welche eine bessere Mittelschule besucht haben als die *freshmen* am MIT". Concerning the quality of faculty and staff, we are on equally slippery ground. We have mentioned in our Report that ETHZ recruits a comparatively high percentage of its faculty from abroad, at least viewed from a European perspective, and that ETHZ can be seen in this respect to be competitive internationally. But this is not the real bottleneck as far as quality is concerned. The real bottleneck must be seen in the fact that, in certain fields, far too few faculty are employed — and some fields cannot be developed at all because such fields may not have the academic aura or funds are said to be lacking for their development. This is a direct consequence of the Humboldtian culture and the corresponding notion of the *Lehrstuhl.* If only one or two faculty members are responsible for a specific academic field when ten would be more appropriate, and if these faculty are not really first rate, generations of students receive a deficient education and training[3]; and if the new faculty are eventually recruited from the population of these former students, the system perpetuates itself. Such grave — and frequent — deficiencies in European or Swiss academic structures cannot be addressed simply by 'coordinative measures' as the 'Schweizerische Wissenschafts- und Technologierat', for instance, tries to suggest [196]. The management of such deficiencies requires an attention to what we have addressed under the term of morphology — and to what FROST and JEAN discuss under the heading of 'adaptive structures' (see Section 10.3 below).

At various points in this Report, we have referred to the link between research and teaching. The link is paradigmatic from a Humboldtian point of view, in that teaching (at a research university) is said to require research. We have referred to the converse "that a basic focus on education [and decent student-faculty ratios, coupled with decent staff-faculty ratios] proves now superior, as far as research output is concerned, to the original [Humboldtian] approach designed to strengthen research" (see page 46). EVA KRUG mentions documents which refer to a psychological aspect of this link. In a faculty survey at MIT [143], factors were listed "that make faculty feel most successful". The factor which was chosen most often was "interactions with students [or] graduates" (46% of the respondents). When asked about the "types of student-faculty contact", most respondents cited "undergraduate advising" (50%), but the second frequent type of interaction was "meals, drinks, socializing" (47%). In other words, even at a dedicated research university, the direct contact with students is seen as rewarding, not as a burden; but these rewards can only be reaped if student-faculty ratios are such as to allow these contacts.

Macro-Organization of Science and Technology Judged from the responses we received, it is unclear to what extent our basic, hypothetical premise regarding the production-morphology nexus is shared. Some commentators — like GUDELA GROTE and WILLI GUJER, or JEAN-PHILIPPE LERESCHE and JUAN-FRANCISCO PERELLON — are inclined to accept our hypothesis intuitively, but they would like to see further in-depth analyses. AANT ELZINGA goes further than that and sees some of his own views corroborated, views which were honed in a range of important science evaluation studies. He refers to a study of the former Swiss Science Council[4] [197] concerning the humanities, a study which we had known, of course, but which we did not cite because of its disciplinary focus. The second study, an evaluation led by

[3] One could even argue that student receive a deficient education in such cases irrespective of the quality of their teachers.

[4] Now 'Swiss Science & Technology Council'.

Max Kaase of the humanities and social sciences at ETHZ, we were unable to look at because of the traditionally discrete way ETHZ handles evaluations. The majority of the commentators take on the position that a range of other factors are involved as well when studying the issue of research productivity (a position we share). Many of these factors appear to be interlinked and culturally tied, at least from our viewpoint, to what we subsume under the notion of morphology.

One aspect which we did only touch on in passing refers to what TERRENCE RUSSELL (in a separate remark) calls the "macro-organization of science and technology". He in turn refers to the 'triple-helix' concept, developed by HENRY ETZKOVITZ and LOET LEYDESDORFF [70, 133, 134]. We did not specifically focus on technology transfer [148] and university-industry-government relations other than to refer to regional impact and outcome analysis (particularly Chapter 6). We also did not specifically cover funding modes (although we were referring to funding issues and their impact on self-organization, change management, and inter-disciplinary research). RUSSELL raises now a number of important points, particularly where he comments on productivity issues. He asks, "Given the assumed advantages of the small-group model, why does the large-group model persist?". Basically, he offers the view that the 'large-group model' survives because it might constitute an (optimal) adaptation to the prevailing (suboptimal) culture and macro-organization of science and technology (and vice-versa). Given this link between morphology and the macro-organization of science and technology, or the particular "triple helix of university-industry-government relations", there would be "no particular impetus for change": the system would be 'locked' in this state of affairs and one part of the system (i.e. the morphology of the institution) could not be changed without the other part (i.e. the 'triple helix' of university-industry-government relations). RUSSELL also "question[s] whether one institution on the small group model could effectively realize [the purported] advantages [of this model] except as a part of a matrix of similarly organized institutions … ".

Given the ongoing, long-standing — and to some extent fruitless — discussion on university reform, in Germany for instance [212, 65, 160], which prompted DIETMAR BRAUN to suggest we should not follow the "sterile Aufgeregtheit" of today's policy-making, we might really think that not much can — or should be — done to change matters.

10.2 Approach, Methodology and Biases

A range of comments pertain to the approach chosen, to methodological aspects, or to concepts used. HERBERT EINSTEIN observes, correctly, that "the Report concentrates on things which can be evaluated by numbers […] or by organizational structures". It is our view that, as long as data is available and relatively unexplored, studies might try to work with this material. This is not to diminish the value of studies which rely on their own empirical observations, as GUDELA GROTE suggested, on the contrary. Both types of studies complement each other.

Concepts Used JEAN-PHILIPPE LERESCHE and JUAN-FRANCISCO PERELLON warn of the trap one might fall into by confusing faculty (as a population of scholars) and *Facultés* or *Fakultäten* (as institutions). They claim BOURDIEU's concept of morphology refers to the latter and not to the former. We are not saying that BOURDIEU is not talking about the transformation of the *Facultés*, but he operationalizes this transformation with the concept of morphology: he specifically uses various ratios to describe the structural setup — i.e. the morphology — of such *Facultés*[5].

The view of LERESCHE and PERELLON who observe that the concept of 'culture' plays an essential role in our Report is correct. They would have welcomed a more precise definition as well as a more profound discussion of the concept and its ramifications, advice which we shall try to heed in the context of future studies; in the present situation, such foci would have easily led to a much more expanded study. WERNER OECHSLIN observes that our thesis concerning national differences in higher education cultures is "irritierend [bzw.] nicht zu Ende gedacht". As a scholar and patron of culture[6], he naturally sees himself as a proponent of an indigenous culture, a position we can fully understand and share. And DANIEL SPRENG fears that in trying to adapt or to emulate, ETHZ might loose whatever advantages the institution still has. These positions open up an area of tension which is worthwhile to explore in greater detail — perhaps by people more qualified in matters of culture than ourselves. While we clearly argue against unreflected national positions, as advocates of autonomous institutions we see ourselves also supporting 'local' cultures.

Higher education has become a vital change agent, and vital aspects of the public ought to be aired.

With regard to Chapter 4, LERESCHE and PERELLON state that our notion of processes remains a "black box", a sentiment which appears to be shared by GUDELA GROTE when she writes that "it would have been more interesting to describe the work process [...] in small vs. large research units and to try to derive assumptions about productivity from that". Here, we would like to answer in general terms: the Report does not discuss 'input', 'output' and 'processes', it discusses 'indicators' of input, output or processes. We agree that a detailed focus on processes, for instance, is interesting and worthwhile, but it was clearly outside the reference frame of the present study.

Aim of the Study and Scientific Approach WILLI GUJER observed that it was unclear to him to whom the Report addresses itself. We thought we had made this reasonably clear in the Foreword (page 8). The study addresses itself to a wider spectrum of interested readers in various functions and positions. Higher education has become a vital change agent in our respective societies, a 'motor' of development, so to speak, and vital aspects of the public ought to be aired. Current issues in higher education — massification, diversification, admission policies, governance and leadership, funding and budgeting measures, accountability, structure and morphology of institu-

[5] See in this respect in particular chapter 4 and the appendix 2.1 of [20].
[6] See: www.bibliothek-oechslin.ch.

tions, adaptive structures and change management, national cultures and continental or global orientations, virtual initiatives, et cetera — demand broad, constant and open debates among all concerned.

The notion of ULRICH TEICHLER, supported to a certain degree by DIETMAR BRAUN, that our study does not follow scientific conventions, might be rooted in a similar concern. Indeed, it was not our aim to present a scientific study in the narrower sense. We had no intention to pretend to be value-free: we do not believe in value-free research and we are convinced great harm can be caused by those who do, particularly if they speak with authority. That is not to say, of course, that we are not in support of quantitative, structural analysis, with a specific focus: quite to the contrary. But our study was much too broad to pursue such an approach. Nor was this our aim (in this particular context): we wanted to contribute to — and enliven — an ongoing discussion and tried to emphasize certain aspects of our higher education system which we thought do not receive proper attention. Our study may be seen as an extended essay, if you will, where we presented our personal views, yes. But do not discount personal views lightly: they are based on years of institutional experience and the study of the views of many other authors. If you discount personal views, you may as well discount management (not management science) altogether. We accept if the study is provocative to some extent, as HANS-JAKOB LÜTHI has pointed out, and we hope that such provocation can be seen to play a constructive role.

The misunderstanding regarding the purpose and the form of the study appears to be in the foreground again when DIETMAR BRAUN charges that “[t]he authors conclude on the base of two institutions”. He would have preferred us to present a theory first, and to test — or try to falsify — this theory subsequently. Although we are great admirers of KARL POPPER [179, 180], we adhere to a broader notion of science. While certain sciences have a descriptive focus, others are normative in nature [206, 38, 39, 207] (i.e. they investigate matters of choice, courses of actions to be pursued, as in engineering or the management sciences), and to restrict the notion of *Wissenschaftlichkeit* to the descriptive sciences only appears — to us at least — inappropriate. We did not generalize from a sample which had only two members, and we did not want to test a theory: we wanted to compare two institutions. This is why we compared the institutions first (in Chapters 3 through 6) and presented some reflections afterwards (Chapters 7 and 8).

Another objection is raised by ULRICH TEICHLER when he admonishes us for our supposed enchantment with academic titles. Keep in mind that we never talked of titles; we talked of functions, of positions. We never claimed that staff members do not assume important advising or teaching roles, and we do not think that “Wissenschaftler ohne Professorenrang [k]eine bedeutsame Betreuungsfunktion für Studierende haben”. But we did claim, implicitly, that senior staff members of academia should have the prospect to join the ranks of the faculty somewhere, provided they are qualified, or they should leave the research university environment altogether. JÜRGEN ENDERS and UWE SCHIMANK observe the following [65]:

> “Die Distanz zwischen der Professorenschaft einerseits und den nicht-professoralen Wissenschaftlern anderseits im Hinblick auf ihre berufliche Verfügungsgewalten und Autonomiespielräume und auf die Möglichkeiten zur Mitsprache

> in den Entscheidungsprozessen ist […] an den deutschen Universitäten — im internationalen Vergleich gesehen — besonders ausgeprägt. Eine machtvolle Symbolik betont die Distanz zwischen dem Nachwuchs und den Professoren […]".

Hopefully, the reader forgives us the following 'non-scientific' statements: We cannot educate ever new generations of scholars in Germany and Switzerland and keep a lid on the faculty population; we should not keep artificial stumbling blocks in the career path of the talented young; we should enhance basic education by improving student-faculty ratios; we should enhance research education by improving staff-faculty ratios. The hierarchical systems we find here prevent a collegial culture SUSAN FROST and PAUL JEAN evoke: it would be naive to think that non-faculty members with teaching or research duties have the same standing in departmental meetings or committees and that they are on an equal footing with faculty members when applying for research grants, et cetera.

10.3 Adaptive University Structures

SUSAN FROST and PAUL JEAN refer to scholars who had studied the transformation of universities, had reflected on adaptive university structures and thought on what makes universities successful. This and their own studies "suggest that successful universities change not merely to be different or to emulate other institutions, but to advance their own particular mission and vision". We agree with their views. They also note that "effective support for scholarship occurs best at the grass-root level and not at the level of centralized bureaucracy". Again, we agree. Our own observations at ETHZ indicate that most important academic initiatives for change in the past — the founding of new departments, institutes or laboratories — were grass-root activities, initiated 'bottom-up' and supported 'top-down'.

Leadership is necessary, particularly where self-interest cannot be counted on to effectuate change.

In contrast to the scholars FROST and JEAN refer to, we have not concentrated on particular substances of a successful adapting behavior; we have not been talking about leadership and have only referred to in passing to entrepreneurial approaches, et cetera. But we did talk about some measures which we feel are indicative of higher education institutions to manage change. Without a change in the structural setup, in the morphology of European research universities, institutions will be severely handicapped to assume pro-active roles, to adapt to change.

Factors of Attraction We agree with HERBERT EINSTEIN, HANS-JAKOB LÜTHI and WERNER OECHSLIN that people stand at the center of a successful university. This has traditionally been the understanding of the presidents of ETHZ, past and present (as well as presidents of other research universities). Without scholars of reputation and recognition, no good doctoral and post-doctoral students can be attracted and — in a competitive environment

— also no good undergraduates. And without excellent faculty, it is very difficult to attract new faculty of repute or promise.

We have discussed these matters in our Report and have alluded to what at ETHZ is referred to as the "Harvard vs. the MIT approach" of faculty recruitment. Faculty recruitment is a delicate matter, to be sure, and it depends on a range of factors or incentives: income prospects, seed moneys, reputation of the institution or department, colleagues, employment prospects for spouses, language abilities, urban crime rates, schooling and housing, access to ski slopes — you name it. Most of these factors are generally recognized as being important. But they alone do not guarantee a faculty which is in a position to turn an institution into a really vibrant place. True, certain groups may achieve excellence, as is the case at ETHZ, but to really turn an institution on one has to pay attention to a structure, to a morphology, which allows talent to blossom and which is supportive of initiative behavior.

Leadership and Academic Culture Not all change, not all adaptations will come to fruition on the base of bottom-up activities alone. Sometimes, leadership appears necessary as well. One of the cases where leadership plays a role, unfortunately, is the furtherance of the opportunities of women, an objective pursued by the former President of ETHZ, Jakob Nüesch, for instance. Leadership is necessary in other cases as well, particularly where self-interest cannot be counted on to effectuate change. In connection with the furtherance of the social sciences and the humanities at ETHZ, AANT ELZINGA mentions the successful launch of the *Collegium Helveticum*, an interdisciplinary research and teaching unit. The formation of the *Collegium Helveticum* is an example of leadership, but we would have preferred to see such academic units developing much more easily on the basis of bottom-up activities. A similar argument, presumably, could be made regarding the project of 'ETH World', a far-reaching vision in support of the formation of an information-technology infrastructure, initially formulated by Vice-President Gerhard Schmitt[7].

To turn an institution on one has to pay attention to a structure, to a morphology, which allows talent to blossom and which is supportive of initiative behavior.

A case of lacking leadership is mentioned by KURT WÜTHRICH[8] when he refers to the "mandatory retirement" of faculty at ETHZ. We don't want to enter the discussion on mandatory retirement here, but it appears clear to us that much talent is wasted by

[7] `www.ethworld.ethz.ch/`.

[8] The Royal Swedish Academy of Sciences announced October 9, 2002, the decision "to award the Nobel Prize in Chemistry for 2002 for the development of methods for identification and structure analyses of biological macromolecules with one half jointly to John B. Fenn, Virginia Commonwealth University, Richmond, USA, and Koichi Tanaka, Shimadzu Corp., Kyoto, Japan, for their development of soft desorption ionisation methods for mass spectrometric analyses of biological macromolecules and the other half to KURT WÜTHRICH, Swiss Federal Institute of Technology (ETHZ), Zürich, Switzerland and The Scripps Research Institute, La Jolla, USA, for his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution". We heartily congratulate KURT WÜTHRICH for receiving this recognition of his work.

practically forcing able members of the faculty out of academia, instead of making use of such scholars in a creative way. One doesn't have to be a reader of the 'New York Review of Books', for instance, to realize that some elder scholars are still very productive. Some years ago at ETHZ, an informal proposal was made to attract prominent academic retirees (from all over the world) to Zürich, in order to enhance the profile and the attractiveness of ETHZ and to strengthen fields such as the history or the philosophy of science[9]. It remained an informal proposal.

Presumably, there are other cases of lacking leadership or governance. Since leadership is a very delicate matter, particularly in Europe or Switzerland, such roles are clearly difficult to fill. Despite vision papers by various people and commissions at ETHZ, which emphasized the need for a stronger focus on the social sciences, for instance, or for more pronounced foci on the intersecting fields of natural sciences on the one hand and the engineering sciences on the other, development appears to be slow (see pp. 30).

Far too high portions of available resources are funneled into existing structures, and not enough resources are available to fund new projects or programs.

We have mentioned that, from a system's point of view, today's complex problems "cannot be understood unless the humanities and the social sciences make — and are allowed to make — their contribution". Conversely, as the language and tools of social sciences and the humanities become more 'mathematical', more quantitative and structural, technical institutes (such as MIT or ETHZ) are in a central position to influence — in a trans-disciplinary way — the future of such fields [7]. Furthermore, despite the fact that ETHZ had a monopoly in Switzerland regarding natural sciences *and* engineering[10], and despite the fact that it has become difficult to distinguish between fields of engineering and the natural sciences, these intersecting fields were not readily recognized of strategic value or — as FROST and JEAN say — as fields "to advance [the] particular mission and vision" of ETHZ.

To be in Charge EVA KRUG refers to an aspect which appears to be in the foreground when comparing cultures of higher education: "MIT puts its future in its own hand. It relies on its [...] resources to consider and implement change [...]"[11]. Paraphrased, KRUG says that MIT relies more than ETHZ on its own resources to effectuate change. While this charge would have to be evaluated in some detail, there is a certain appeal to it, at least from a Swiss perspective. We presume that the Swiss Federal Institutes of

[9] Note that the history of (particular) sciences is frequently the domain of representatives of these sciences, not of historians. A similar — but perhaps not equally strong — argument can be made in the case of philosophy of science.

[10] This monopoly has recently ceased to exist because EPFL, formerly an engineering school in the stricter sense, has taken over certain sections of the Sciences from the University of Lausanne.

[11] In this quote, we have taken out the word 'own' in "own resources" to indicate that, in KRUG's view, MIT relies on its resources available to effectuate change. That a sizable portion of resources are public in origin is not relevant in this particular context.

Technology, together with the natural sciences *Fakultäten* of the cantonal Swiss universities, are amongst the best funded higher education institutions in Europe, and this is necessary and good. But despite this relatively high level of funding, the management options for change generally appear extremely slim. ETHZ has been plagued by lacking funds for some time now, problems which can be traced in part to internal resource allocation mechanisms which do not meet the demands of the day: far too high portions of available resources are funneled into existing structures, and not enough resources are available to fund new projects or programs.

In response to our observation of the larger population of non-academic staff at MIT — and in response to our favorable perception of this phenomenon, Ulrich Teichler would like to know how we would react if ETHZ were to consider reducing academic staff in favor of the central administration. It is interesting — and revealing to some extent — that he would pose this particular question. We have already alluded to what we would recommend: not to reduce academic faculty or staff, but the broadening of the funding base (from public and private sources)[12]. This, in our view, appears to be first of all a matter of leadership. In the mid 1990s we learned that Swiss industry had become the number one foreign investor in the US high-tech business, surpassing all great European nations [51]: a comparable amount of funds were invested annually by Swiss firms in US high-tech companies and R&D fields as in the entire Swiss university system ($2.3 billion). Recently, we learned that Novartis is opening up a $250 million research center at MIT's Tech Square[13]. Perhaps, if one where to perceive the university in a different way, the broadening of the resources base would not be an impossible mission after all[14].

The question is not whether universities should adapt to aspects of a contextual culture which academics feel are wrong; the question is whether universities are in a position to adapt to and shape developments which academics feel are right.

Having made these remarks, we would like to stress that we are not proponents of change as such and we are not advocating that European or Swiss institutions should simply emulate US institutions. We clearly share the concern of Braun regarding "marketization" or the "contractualization and the privatization of knowledge", in spite of what may be interpreted otherwise (on the base of our remarks above). Whether Europe is really characterized by a "tradition of a 'free' and non-instrumentalized academic culture", as Braun suggests, is — from out point view — questionable, but this may be beside the point. The question is not whether universities should adapt to aspects of a contextual culture which academics feel is wrong; the question

[12] A range of offices at MIT, in support of activities such as licensing activities or technology transfer, et cetera, are self-supporting.

[13] May 6, 2002: see: `http://web.mit.edu/newsoffice/nr/2002/novartis.html`.

[14] It is noteworthy that in the course of the discussions on the future use of the gold reserves of the Swiss National Bank, which extended over many years, no proposal gained ground which would earmark portions of these (sizable) resources for higher education. Perhaps after the inconclusive vote of September 22, 2002, this may change. See [215].

is whether universities are in a position to adapt to and shape developments which academics feel are right.

When we talk of the empowerment of people, we may perhaps also be talking of the 'empowerment' of institutions. This is the essence of the 'learning organization'. We recall the dictum of Niklaus Wirth, the eminent computer scientist of ETHZ, that the educational programs of ETHZ should not meet market demands, but shape these. This is similar to the recollection of HERBERT EINSTEIN concerning Forrester's observation that "[w]hen a problem area is generally recognized, it is time for MIT to get out of it". The question is here whether universities have the proper setup, structure, or morphology to institute the changes deemed necessary.

Academic Ratchet, Administrative Lattice, and Professionalisation RUSSELL refers to two concepts which were introduced by WILLIAM MASSY and ROBERT ZEMSKY, the "academic ratchet" and the "administrative lattice" [147, 146]. The concepts were introduced in the context of discussions on budgeting systems. Both concepts refer to forms of what we might call 'sectorial' adaptations which we normally view as sub-optimal when we look at the system as a whole. The first concept refers to expectations or claims regarding resource allocations to academic units (institutes, departments, etc.) by the university, claims which are normally difficult to combat (and which tend to increase over time). The second concept refers to a natural tendency towards better work and professional improvement — a tendency we can observe in our own aspirations — which might lead to overhead-growth and bureaucracy. To combat these tendencies, modern budgetary systems rely on block grants (*Globalbudget*) and various accounting and resources-transfer-schemes [147, 237]. The block grant idea is gradually being adopted by European institutions and championed under the umbrella of New Public Management (see below). But the modern accounting and resources-transfer-schemes frequently cannot be implemented in institutions in Europe because other requirements are lacking: properly implemented course credit systems (to manage the supply of courses and the accounting of educational transfer services from one department to another); and a proper distinction of resource allocation between teaching and research.

Modern budgetary systems play a very important — even central — role in the proper management of institutions. When we were talking of professionalisation, and when we referred to the size of MIT's non-academic staff, we were conscious of the "administrative lattice", of course. Our notion of professionalisation is not in conflict with Peter Scott's notion of professional organizations "anchored in the scientific community". We are not advocating a bureaucracy, or a bureaucratic caste vis-à-vis academics, as BRAUN appears to fear. But to run a modern university, one needs features which we rarely find well developed in European — or Swiss — universities: stronger role differentiations between teaching, research and administrative tasks; a broader distribution of authority, i.e. a more pronounced collegial setup, where administrative or management functions can be delegated to more people; and a professionalisation in administration or management in that these people perceive themselves not only as professionals in their academic field but are willing to further their professionalisation also in administrative, management or institutional research matters.

This interplay between academia and administration is far more developed in the US than in Europe, and there exist well developed platforms for the exchange and the furtherance of ideas: professional organizations which cater to institutional research and various forms of university or research administration, addressing people in various functions (from the administrative assistant to the president of an institution); post-graduate or continuing education courses; publication series (open to administrators as authors). In contrast, there are few European organizations with a truly continental reach, and they are small in comparison[15]. Lastly, US academics will switch much more freely between academic and administrative duties (and vice versa). Academics (in management, policy sciences, operations research, etc.) are willing (and in a position) to apply their know-how right where they work: in their own institutions [6].

Having referred to modern budgetary systems, we may respond briefly to HERBERT EINSTEIN's comment regarding our assessment of the setup for inter-disciplinary research at the two institutions. "In most instances at MIT", he writes, "it is [to] get the research [and] then divide it up". TERRENCE RUSSELL, too, makes the point that "[i]n the MIT model, funds are not 'redistributed', they [are] distributed from the outside on the basis of a competitive research model". Our view is not in contrast to what both EINSTEIN and RUSSELL say. Let us try to explain. If one contrasts European or US research universities, one observes that US institutions are much more flexible in the formation of research units or educational programs: faculty from differing departments can much more easily find themselves in the pursuance of specific goals of their own choice. This is why we were talking of 'research fragmentation', and AANT ELZINGA accepted this notion when he referred to "cognitive fragmentation". US faculty appears to be more flexible than most of their European peers, as HANS-JAKOB LÜTHI observes as well, because they have greater freedom to 'invest' their own resources in projects which cross departmental boundaries. This is another aspect of the "venture capital model" RUSSELL refers to. If funds are distributed to faculty or principal investigators, from within or without, these funds are frequently "redistributed" to common research or educational programs. The institution itself — or even outside agencies — may provide additional funds directly if the common research or educational programs justify particular incentives. Modern budgetary systems greatly ease the accounting of such flows of resources. Clearly, once a research grant has been obtained by a research unit, then it may be time "to divide it up" among those who are involved.

New Public Management (NPM) DIETMAR BRAUN is correct when he sus-

[15] An annual meeting of one the large US higher education associations (AIR, SCUP, AAHE, et cetera) will draw 1,000 to 2,000 participants; a corresponding European meeting (EAIR, EARMA, SRHE, etc.) will draw 200 to 400 participants. Participation rates in Europe are very uneven: participation rates are high among members of the UK, the Netherlands, and the Scandinavian countries, and low in Germany, France, Italy. Casual observations over an extended period attest to the fact that very few Swiss administrators — or academics in administrative functions — will attend these meetings.

pects that we are critical of NPM. Not that we are critical of attempts to renew public management, of course: we ourselves argue along these lines. The term alone makes one suspicious. Why the prefix 'New'? Every field develops, perhaps not smoothly, perhaps unevenly [128, 203, 129]. Imagine if we were talking of New Physics, New Chemistry, New Biology, et cetera. This would indicate that physics, chemistry or biology had not constantly renewed themselves in the past, that the fields were locked in a mode of thinking (i.e. in generally accepted 'ideologies') which prevented development, and that very major paradigmatic changes were necessary, i.e. revolutions, to move the system of thinking forward. And to what refers NPM? To a field of (social) science which is part of our universities? Or to a practice of governments?

BRAUN is also correct when he observes that some of our views are conform with positions which might carry now the label of NPM. But if you look at the history of higher education, and if you observe the dominance of US research universities of today, you will also observe that many of the ingredients which appear instrumental in generating this dominance — governance, accreditation, evaluation, autonomy, graduate schools, attention to morphology, diversification, funding and budgeting systems, use of textbooks, et cetera — have early roots and very long histories of constant, gradual developments. HERBERT EINSTEIN appears correct when he points to the "continuing self-renewal [as] the main difference between ETHZ and MIT" (or between higher education systems in the US and Europe). There is not much new in NPM — but a range of things seem wrong. Observe the difficulties we have in agreeing on how to measure performance. Why should we, in light of these difficulties, put that many eggs into the basket of performance-based budgeting, put that much emphasis on *Leistungsvereinbarungen* and *Leistungsaufträge*? Why should we try to steer universities on the basis of this premise when none of the US elite universities (public or private) is steered this way? On the other hand, if we observe 'good practice' examples at US institutions or the US higher education system in general, why are we reluctant to learn from these?

There is not much new in NPM — but a range of things seem wrong.

The answer, it appears, has to do with a 'system's argument': because of the specific — national — features which characterize European higher education systems, because of a frequent lack of competition and 'market' conditions, quasi-market conditions are generated in an attempt to simulate an envisaged 'proper' higher education environment (which is said to be lacking). Why not implement (gradually) conditions which would directly create the markets which are missed[16]? If we keep the European research university in a protected niche, it will eventually completely vanish from the roaster of elite institutions[17]. The results of such policies would be disastrous for Europe,

[16]Presumably, this is one of the goals of the Bologna process. RICHARD ERNST, too, seems to favor more competitive elements; see [66].

[17]With clear implications for ETHZ, for instance. The notion that we have juxtaposed incomparable entities, MIT with its quasi-continental impact and ETHZ with a more restricted domestic focus, is misleading if we look into the future. In the future, ETHZ will have to assume a much more pronounced European role to survive as a leading research university.

economically as well as intellectually.

10.4 Future Work

As we have said in the introduction to this Chapter, space and time prevents us to touch upon all the individual annotations which were offered by the commentators. The reflections and commentaries which we find in Chapter 9 present a wealth of information and ideas which are of use in the structuring of future studies. Some of the positions presented are not consensual: we find commentators on differing sides of the spectrum of ideas. But we feel sure the readers of this Report will profit from the various expositions and suggestions offered.

A range of current studies focus on governance and the government-university interface [10, 24, 98, 123, 209]. While this constitutes a very important line of research to be pursued, it does not properly address our main concern here. We view proper governance and government-university interfaces as co-requisites to a proper morphology — and vice versa. Both are necessary, in our view, and it would be fruitless to discuss the subordination of one under the other. The commentaries received (see Chapter 9) attest to the fact that some commentators value the importance of governance, of leadership, for instance. But governance and leadership require proper structures, proper morphologies. Hence, future studies along the lines sketched out in the present Report might be directed towards the production-morphology nexus, while other studies might focus more on issues which were judged to be more peripheral in the present Report:

- In our view, additional studies will be necessary to shed more light on a possible performance gradient between US institutions and institutions elsewhere (based on bibliometric data).

- If a performance gradient appears credible, additional elaborations would be necessary to explore the causes of such differences in performance. Various 'cultural' factors may play a role which ought to be explored using scientometric techniques, as TERRENCE RUSSELL suggested.

- One avenue, clearly, would be to test our hypotheses concerning the production-morphology nexus, perhaps on the basis of general Cobb-Douglas production functions [90, 91].

HANS-JAKOB LÜTHI suggested[18] to use 'Data Envelopment Analysis' (DEA) [109] as a possible methodology to assess efficiency (or effectiveness) differentials separating institutions, a technique which has been shaped by ABRAHAM CHARNES and WILLIAM W. COOPER [37] and which is based on the theory of Linear Programming [55]. We should emphasize, however, that DEA is at least as demanding (regarding the availability of data) as

This poses not only a clear challenge for ETHZ but for Swiss higher education policies as a whole.

[18] Private communication.

other econometric techniques referred to above: it will rely on establishing a proper 1–1 correspondence between input and output indicators.

Apart from studies which would focus directly on the performance-morphology link, a full spectrum of further issues has been touched upon in the present Report, issues which relate to the measurement (and assessment) of various indicators used in a process model of higher education institutions. At least some of these will be worth investigating as well. Furthermore, some commentators may have implicitly preferred a decoupling of the study of performance and morphology — performance may be furthered by other means than to change the morphology, or morphological adaptations appear advisable irrespective of their impact on performance —, an avenue of future investigation worth following as well.

Part III

Appendices

Appendix A

Context

A.1 Funding of Education and Research & Development

The section contains four tables:

- National Educational Expenditures in % of GDP (Table A.1).
- R&D-Expenditures in % of GDP (Table A.2).
- R&D-Expenditures in % of GDP in Selected US-States (Table A.3).
- Average Academic Salaries at Selected US Institutions (Table A.4).

Table A.1: NATIONAL EDUCATIONAL EXPENDITURES (IN % OF GDP, YEAR 1995), see [170].

	Expenditures (% of GDP)	
NATION	Total	Tertiary Sector
Sweden	6.6	3.6
Switzerland	5.5	3.0
US	5.0	2.9
France	5.8	2.4
Canada	5.8	—
UK	4.6	2.2
Germany	4.5	2.2
Japan	3.6	1.8
Italy	4.5	1.5

Table A.2: R&D-Expenditures in % of GDP (Figures relate to the year 1997; exceptions are the cases of Switzerland (1996) and Sweden (1995); based on [175, 199].

Nation	Expenditures (in % of GDP)
Sweden	3.59
Japan	2.92
US	2.60
Switzerland	2.57
Germany	2.31
France	2.23
UK	1.87
Canada	1.60
Italy	1.08

Table A.3: R&D-Expenditures in % of GDP in selected US-States (1998), based on [13].

State	Expenditures (% des GDP)
Delaware	7.6
New Mexico	6.4
Massachusetts	5.6
Rhode Island	5.5
Maryland	4.9
Michigan	4.6
Washington	4.4
California	3.9
Idaho	3.6

Table A.4: Average Academic Salaries at selected US institutions (1,000 $ per Academic Year of 9 months, 2000-01), by Rank (P=Professor, AP=Associate Professor, aP=Assistant Professor); based on [5].

Institution	P	AP	aP
California Institute of Technology	122.2	85.9	73.4
Carnegie Mellon University	105.0	73.5	68.1
Harvard University	135.2	79.2	71.6
Massachusetts Institute of Technology	117.0	78.7	72.1
Stanford University	126.7	88.1	69.1
University of California (Berkeley)	113.6	73.2	62.5
University of Illinois (Urbana)	95.6	66.3	56.8
University of Michigan (Ann Arbor)	105.2	73.3	59.7
University of Texas (Austin)	94.1	60.8	57.3
University of Virginia	106.2	71.4	56.6

A.2 Program for International Student Assessment (PISA)

The section contains the following 2-tables:

- Combined Reading Literacy, Highest vs. Lowest Proficiency (Table A.5).
- Mathematical Literacy, High vs. Low Proficiency (Table A.6).
- Scientific Literacy, High vs. Low Proficiency (Table A.7).
- Combined Reading Literacy vs. Scientific Literacy (Table A.8).
- Combined Reading Literacy vs. Mathematical Literacy (Table A.9).
- Scientific Literacy vs. Mathematical Literacy (Table A.10).
- Perceived Ability to Use Computers, High vs. Low Proficiency (Table A.11).

Table A.5: PISA, COMBINED READING LITERACY: National Results by Highest Proficiency Level (Level 5) vs. Lowest Proficiency Level (below Level 1); $N = 27$; based on Table 2.1a of [172], p. 246.

		HIGHEST PROFICIENCY LEVEL:	
		above average	below average
LOWEST PROFICIENCY LEVEL:	above average	Australia Canada Finland Ireland Japan New Zealand Sweden United Kingdom	Austria Denmark France Iceland Korea Spain
	below average	Belgium Norway United States	Czech Republic Germany Greece Hungary Italy Luxembourg Mexico Poland Portugal Switzerland

Table A.6: PISA, MATHEMATICAL LITERACY: National Results by High Proficiency Level (90th percentile) vs. Low Proficiency Level (10th percentile); $N = 27$; based on Table 3.1 of [172], p. 259.

	HIGH PROFICIENCY LEVEL: above average	HIGH PROFICIENCY LEVEL: below average
LOW PROFICIENCY LEVEL: above average	Australia	Czech Republic
	Austria	Denmark
	Belgium	Hungary
	Canada	Iceland
	Finland	Ireland
	France	Norway
	Japan	Sweden
	Korea	
	New Zealand	
	Switzerland	
	United Kingdom	
LOW PROFICIENCY LEVEL: below average		Germany
		Greece
		Italy
		Luxembourg
		Mexico
		Poland
		Portugal
		Spain
		United States

Table A.7: PISA, SCIENTIFIC LITERACY: National Results by High Proficiency Level (90th percentile) vs. Low Proficiency Level (10th percentile); $N = 27$; based on Table 3.3 of [172], p. 261.

	HIGH PROFICIENCY LEVEL: above average	HIGH PROFICIENCY LEVEL: below average
LOW PROFICIENCY LEVEL: above average	Australia	Iceland
	Austria	Norway
	Canada	United States
	Czech Republic	
	Finland	
	Ireland	
	Japan	
	Korea	
	New Zealand	
	Sweden	
	United Kingdom	
LOW PROFICIENCY LEVEL: below average	Belgium	Denmark
	France	Germany
	Hungary	Greece
		Italy
		Luxenbourg
		Mexico
		Poland
		Portugal
		Spain
		Switzerland

Table A.8: PISA, COMBINED READING LITERACY VS. SCIENTIFIC LITERACY: National Results by Performance Levels ($N = 23$); based on Table 3.6 of [172], p. 264.

		SCIENTIFIC LITERACY:	
		above average	below average
COMBINED READING LITERACY:	above average	Australia Austria Finland France Ireland Japan Korea Norway Sweden United Kingdom	Belgium United States
	below average	Czech Republic	Denmark Germany Greece Hungary Italy Mexico Poland Portugal Spain Switzerland

Table A.9: PISA, COMBINED READING LITERACY VS. MATHEMATICAL LITERACY: National Results by Performance Levels ($N = 23$); based on Table 3.6 of [172], p. 264.

		MATHEMATICAL LITERACY:	
		above average	below average
COMBINED READING LITERACY:	above average	Australia Austria Belgium Finland France Ireland Japan Korea Sweden United Kingdom	Norway United States
	below average	Denmark Switzerland	Czech Republic Germany Greece Hungary Italy Mexico Poland Portugal Spain

Table A.10: PISA, SCIENTIFIC LITERACY VS. MATHEMATICAL LITERACY: National Results by Performance Levels ($N = 23$); based on Table 3.6 of [172], p. 264.

		MATHEMATICAL LITERACY: above average	MATHEMATICAL LITERACY: below average
SCIENTIFIC LITERACY:	above average	Australia Austria Finland France Ireland Japan Korea Sweden United Kingdom	Czech Republic Norway
	below average	Belgium Denmark Switzerland	Germany Greece Hungary Italy Mexico Poland Portugal Spain United States

Table A.11: PISA, PERCEIVED ABILITY TO USE COMPUTERS: National Results by High Proficiency Level (Top Quarter) vs. Low Proficiency Level (Bottom Quarter); $N = 16$; based on Table 4.11 of [172], p. 275.

		HIGH PROFICIENCY LEVEL: above average	HIGH PROFICIENCY LEVEL: below average
LOW PROFICIENCY LEVEL:	> average	Australia Belgium Canada New Zealand United States	Sweden
	≤ average	Norway Denmark Ireland Luxembourg	Czech Republic Finland Germany Hungary Mexico Switzerland

A.3 Third International Mathematics and Science Study (TIMSS)

Table A.12: TEST SCORES OF THE "THIRD INTERNATIONAL MATHEMATICS AND SCIENCE STUDY", EIGHT'S STUDY YEAR, by Selected Nations (or States, Districs); the Scale of Scores ranges from 200 [lowest score] to 800 [highest score]; based on [161, 170]).

	1995	1999	
NATION (*District, State*)	Math	Math	Science
Korea	607	587	549
Japan	605	579	550
Naperville, IL	—	569	584
Belgium (flemish community)	565	558	535
First Consort, IL	—	560	565
Czech Republic	564	520	539
Switzerland	545	—	—
Montgomery County, MD	—	537	531
Netherlands	541	540	545
Austria	539	—	—
France	538	—	—
Hungary	537	532	552
Sweden	519	—	—
Michigan	—	517	544
Massachusetts	—	513	533
Germany	509	—	—
UK (England)	506	496	538
Denmark	502	—	—
US	500	502	515
Missouri	—	490	523
Greece	484	—	—
Italy	—	479	493
Chicago Public Schools, IL	—	462	449
Portugal	454	—	—
Miami Dade County, FL	—	421	426
Indonesia	—	403	435

A.4 Admission and Retention Management

The following tables are included:

- University of California, Enrollment by Ethnic Group (Table A.13).
- High School Graduation Rates in the District of Zürich (Table A.14).
- Entry-Rates for University-Level new Entrants (Table A.15).
- Six-Year Graduation Rates at Selected Public and Private US Universities (Table A.16).

Table A.13: UNIVERSITY OF CALIFORNIA: Enrollment by Ethnic Group, in % (Year 2000); 'other UoC' refers to all institutions of the University of California Systems (exept the UoC at Berkeley), based on [192].

ETHNIC GROUP	Berkeley	other UoC
African-American	4.3	2.9
American Indian	0.6	0.6
Asian-American	36.8	29.1
Chicano	6.8	10.2
East Indian/Pakistani	4.4	2.5
Filipino-American	3.9	5.3
Latino	2.8	3.2
Other	1.7	1.9
Unknown	9.2	6.7
White	29.5	37.4
Total	100.0	100.0

Table A.14: HIGH-SCHOOL GRADUATION RATES [MATURITÄTSQUOTEN] OF CORRESPONDING AGE COHORTS, by Selected Municipalities in the District [Kanton] of Zürich (Year 2000), based on [214].

MUNICIPALITY	Rate (%)
Zumikon	53.7
Zürich (City Districts [Kreise] 1,7,8)	45.8
Maur	43.3
Küsnacht	38.5
Meilen	36.6
Zollikon	36.1
District of Zürich	18.1

Table A.15: Entry-Rates for University-Level new Entrants (in % of Age Cohort) and Age at First Enrollment (Year 1996), by Nation (the first percentile measure is the age which is not exceeded by 20% of the cohort, the second indicates the age not exceeded by 50% of the cohort and the third by 80% of the cohort); based on [171] (and Table C3.1 on p. 183 there).

		Age at Percentile:		
NATION	Entry Rate (%)	20%	50%	80%
Switzerland	16	20.2	21.3	23.4
Germany	27	20.1	21.6	25.0
Austria	29	19.1	20.4	23.4
Netherlands	34	18.7	20.2	24.0
Denmark	35	21.4	23.6	29.4
Hungary	35	18.9	20.3	25.3
United Kingdom	41	18.5	19.5	24.3
Finland	45	19.8	21.4	26.5
US	52	18.3	19.0	24.2

Table A.16: SIX-YEAR GRADUATION RATES (OF 1994/95 ENTERING FRESHMEN) AT SELECTED PUBLIC AND PRIVATE US UNIVERSITIES (in %), based on `www.ais.unc.edu/ir/fb0102/0t15.html`.

	INSTITUTION:	Graduation Rate (%)
PUBLIC UNIVERSITIES	University of California (Berkeley)	83
	University of California (Los Angeles)	80
	Georgia Institute of Technology	69
	University of Illinois (Champaign)	76
	Indiana University (Bloomington)	65
	University of Maryland (College Park)	64
	University of Michigan (Ann Arbor)	82
	University of Minnesota	50
	University of North Carolina (Chapel Hill)	79
	University of Pittsburgh	60
	Rutgers University	75
	University of Texas (Austin)	69
	University of Virginia	91
	University of Washington	68
	University of Wisconsin (Madison)	76
PRIVATE AND	Columbia University & Barnard College	87
	Cornell University	90
	Duke University	93
	Harvard University	96
	Northwestern University	92
	University of Pennsylvania	91
	Princeton University	97
	University of Southern California	73
	Stanford University	93
	Syracuse University	74
	Yale University	95

A.5 Doctoral Studies

The section contains the following tables:

- US Statistical Profile of Doctorate Recipients (Table A.17).
- Percentages of Doctoral Degrees in the Natural Sciences and in Engineering which were Conferred to International Students, by Nation (Table A.18).
- US Doctorates of Asian Students in the Fields of National Sciences and Engineering (Table A.19).

Table A.17: US STATISTICAL PROFILE OF DOCTORATE RECIPIENTS (YEAR 2000): by Major Field, Percent Share of Total, Percent Women, Percent Non-US Citizens (Temporary Visa), Median Age at Doctorate, Percent with Doctorate in same Field as Baccalaureate, Percent with Postdoctoral Study Plans, based on [104] (and Appendix Table A–3a on pp. 72).

FIELD	Share (%)	Women (%)	Non-US (%)	Age (years)	Baccalaureate in same Field (%)	Postdoctoral Plans (%)
Physical Sciences	14.7	24.1	35.6	30.7	62.6	39.3
Physics & Astronomy	3.4	14.7	35.9	30.3	69.5	48.3
Chemistry	4.8	31.4	32.6	29.8	73.7	47.6
Earth-, Atmospheric & Marine Sciences	1.9	30.3	26.7	33.4	41.0	45.9
Mathematics	2.5	24.6	42.2	30.4	69.5	30.9
Computer Sciences	2.1	16.5	41.9	32.9	37.0	9.5
Engineering	12.9	15.7	45.9	31.4	74.0	19.9
Life Sciences	20.6	46.9	25.7	32.1	49.3	53.8
Biochemistry	1.9	41.8	29.5	30.2	28.7	74.5
Other Biosciences	12.3	45.2	22.9	31.2	53.8	66.5
Health Sciences	3.8	66.9	19.3	38.2	43.3	17.1
Agricultural Sciences	2.6	28.8	45.4	34.4	51.4	33.5
Social Sciences	17.2	54.5	14.6	33.0	58.3	20.6
Psychology	8.9	66.6	4.5	32.2	61.9	29.6
Economics	2.3	26.9	48.6	31.7	55.2	6.6
Anthropology & Sociology	2.6	58.2	13.5	35.1	76.8	17.0
Political Science & International Relations	1.8	35.1	14.3	33.5	53.5	9.1
Other Social Sciences	1.8	44.8	22.3	35.9	22.8	11.3
Humanities	13.6	50.2	13.1	34.8	47.9	7.8
Education	15.5	64.9	8.4	44.4	33.7	4.8
Professional Fields	5.5	41.7	23.6	37.8	30.5	5.0
Business & Management	2.6	31.7	27.6	36.7	32.0	3.3
Other Professional	2.9	50.7	20.0	39.0	29.3	6.6
Total	100.0	43.8	23.3	33.6	52.3	25.1

Table A.18: Percentages of Doctoral Degrees (in 1995) in the Natural Sciences and in Engineering which were Conferred to International Students: by Nation in which the Doctorate was Conferred; see [166].

Nation	Natural Sciences	Engineering
Germany	7.9	15.8
France	29.1	34.2
Japan	22.1	32.2
United Kingdom	28.5	49.1
US	40.5	57.9

Table A.19: US Doctorates of Asian Students in the Fields of National Sciences and Engineering, as a Share of Total Number of Doctorates by Asian Students (Year 1996, in %): by Citizenship of Students; see [166].

Nation	Natural Sciences	Engineering
China	28.0	11.5
India (1994)	9.3	11.2
Japan	0.1	0.1
South Korea	13.5	10.1
Taiwan	25.9	33.0

Appendix B

Fact-Book MIT

The present appendix contains information relating to (i) faculty and staff, and (ii) students and degrees. Further information is available under the address of MIT's Office of the Provost, Institutional Research[1].

B.1 Faculty and Staff

The section contains two tables:

- MIT, Categories of Personnel (Table B.1).
- MIT, Number of Employees, by School or College (Table B.2).

B.2 Students and Degrees

The section contains the following tables:

- MIT, Number of Undergraduates and Graduate Students, by School or College (Table B.3).
- MIT, Total Number of Degrees Awarded, by School or College (Table B.4).
- MIT, School of Architecture, Number of Degrees Awarded (Table B.5).
- MIT, School of Engineering, Number of Degrees Awarded (Table B.6).
- MIT, School of Humanities and Social Science, Number of Degrees Awarded (Table B.7).
- MIT, Sloan School of Management, Number of Degrees Awarded (Table B.8).
- MIT, School of Science, Number of Degrees Awarded (Table B.9).

[1] `http://web.mit.edu/ir/`.

Table B.1: MIT, Categories of Personnel, based on [142].

Faculty Full Professors, Associate Professors (with tenure), Associate Professors (without tenure), Assistant Professors.

Academic Staff Visiting Faculty, Visiting Lecturers, Visiting Scientists or Scholars, Adjunct Faculty, Instructors, Technical Instructors, Senior Lecturers, Retired Faculty, Lecturers, Postdoctoral Associates, Postdoctoral Fellows, Coaches, Other Academic, Affiliates, Senior Research Associates, Senior Research Scientists, Senior Research Engineers.

Research Staff Principle Research Associate, Scientist, Engineer; Technical Research Staff.

Administrative and Technical Staff Administrative Staff (having professional and administrative in the central and departmental administration).

Support and Service Staff Support Staff (involving primarily clerical and secretarial duties in support of data processing operations, library and accounting functions); Service Staff positions include all union-represented, hourly-paid classifications.

Table B.2: MIT, Faculty and Staff: Number of Employees, by School or College (Yearly [rounded] Averages 1999-2001), based on [139]; Total MIT refers to the Fall of 2000; Figures on other Employment are estimates.

		Staff:					
Schools (or Program):	Faculty	Academic	Research	Administrative Technical	Support	Service	Total
School of Architecture & Planning	70	122	38	48	62	—	340
School of Engineering	335	626	220	100	256	24	1,561
School of Humanities & Social Science	148	224	7	41	79	—	500
Sloan School of Management	90	67	12	85	59	—	313
School of Science	260	785	311	60	162	82	1,660
Health Sciences & Technology	5	169	24	8	13	1	220
Total Academic	908	1,993	612	342	632	107	4,595
other Employment	39	752	204	1,411	871	740	3,996
Total MIT	947	2,745	816	1,753	1,503	827	8,591

Table B.3: MIT, STUDENTS: Number of Undergraduates and Graduate Students, by School or College (Yearly [rounded] Averages 1999-2001), based on [139] (MIT students do not enroll in an academic program until the 2nd year; for the purpose of this table, first year students, by program, were estimated in function of Total First Year Students and the numbers of the undergraduates in the 2nd to 4th years).

			Post-Graduates:			
SCHOOLS (OR PROGRAM):	First Year	2nd to 4th Year	Masters Level	Doctoral Level	Non-Resident Special	TOTAL
School of Architecture & Planning	21	74	360	136	57	647
Media Arts & Sciences	—	—	73	60	1	134
School of Engineering	573	2,020	1,382	1,094	56	5,124
School of Humanities & Social Science	40	141	19	256	52	507
Sloan School of Management	62	219	779	76	20	1,157
School of Science	225	791	29	932	26	2,003
Health Sciences & Technology	21	74	360	136	57	647
TOTAL	942	3,318	3,002	2,690	269	10,220

Table B.4: MIT, TOTAL NUMBER OF DEGREES AWARDED 1999-2000, by School (or College).

SCHOOL (OR COLLEGE):	B.S.	M.S.	Professional Masters	Ph.D.	Sc.D.	TOTAL
School of Architecture	30	97	77	30	—	234
School of Engineering	715	482	270	213	11	1,691
School of Humanities & Social Science	98	15	—	45	—	158
Sloan School of Management	71	105	360	21	—	557
School of Science	339	26	—	119	—	484
Whitaker College	—	2	—	8	1	11
whithout course specification	—	31	—	—	—	31
Woods Hole Oceonographic Inst. (joint degrees)	—	5	1	26	1	33
TOTAL	1,253	763	708	462	13	3,199

Table B.5: MIT, SCHOOL OF ARCHITECTURE: Number of Degrees Awarded, 1999-2000.

DEGREE PROGRAM:	B.S.	M.S.	M.Arch. MCP	Ph.D.	TOTAL
Architecture	—	—	19	8	27
Architecture Studies	—	22	—	—	22
Art and Design	23	—	—	—	23
Building Technology	—	2	—	—	2
Media Arts and Sciences	—	26	—	13	39
Media Technology	—	5	—	—	5
Planning	7	—	—	—	7
Real Estate Development	—	36	—	—	36
Urban Studies & Planning	—	2	58	9	69
Visual Studies	—	4	—	—	4
TOTAL	30	97	77	30	234

Table B.6: MIT, SCHOOL OF ENGINEERING: Number of Degrees Awarded, 1999-2000.

DEGREE PROGRAM:	B.S.	M.S.	M.Eng. Engineer	Ph.D.	Sc.D.	TOTAL
Aeronautics and Astronautics	33	48	7	18	1	107
Chemical Engineering	87	8	—	46	—	141
Undesignated	10	—	—	—	—	10
Chemical Engineering Practice	—	29	—	—	—	29
Civil Engineering	14	—	—	—	—	14
Civil and Environmental Engineering	—	47	48	13	—	108
Undesignated	2	—	—	—	—	2
Computer Science and Engineering	185	—	—	—	—	185
Electrical Science and Engineering	78	—	—	—	—	78
Electrical Engineering and Computer Science	124	70	191	78	4	467
Engineering and Management	—	59	—	—	—	59
Environmental Engineering Science	14	—	—	—	—	14
Logistics	—	—	16	—	—	16
Materials Science and Engineering	38	22	—	19	2	81
Undesignated	3	—	—	—	—	3
Mechanical Engineering	104	105	1	24	2	236
Undesignated	9	—	—	—	—	9
Naval Architecture and Marine Engineering	—	7	—	—	—	7
Naval Engineer	—	—	6	—	—	6
Nuclear Engineering	11	14	1	5	2	33
Ocean Engineering	3	11	—	4	—	18
Ocean Systems Management	—	3	—	—	—	3
Technology and Policy	—	41	—	1	—	42
Technology, Management and Policy	—	—	—	3	—	3
Toxicology	—	4	—	2	—	6
Transportation	—	14	—	—	—	14
TOTAL	715	482	270	213	11	1,691

Table B.7: MIT, SCHOOL OF HUMANITIES AND SOCIAL SCIENCE: Number of Degrees Awarded, 1999-2000.

DEGREE PROGRAM:	B.S.	M.S.	Ph.D.	TOTAL
Economics	56	4	23	83
Foreign Languages and Literatures	2	—	—	2
Humanities	1	—	—	1
Humanities and Engineering	5	—	—	5
Humanities and Science	4	—	—	4
Linguistics	—	2	4	6
Linguistics and Philosophy	1	—	—	1
Literature	8	—	—	8
Music	8	—	—	8
Philosophy	3	—	4	7
Political Science	8	7	10	25
Science, Technology, and Society	—	2	4	6
Writing	2	—	—	2
TOTAL	98	15	45	158

Table B.8: MIT, SLOAN SCHOOL OF MANAGEMENT: Number of Degrees Awarded 1999-2000.

DEGREE PROGRAM:	B.S.	M.S.	MBA	Ph.D.	TOTAL
Management	—	47	360	13	420
Management Science	71	—	—	—	71
Management of Technology	—	49	—	—	49
Operations Research	—	9	—	8	17
TOTAL	71	105	360	21	557

Table B.9: MIT, SCHOOL OF SCIENCE: Number of Degrees Awarded 1999-2000.

DEGREE PROGRAM:	B.S.	M.S.	Ph.D.	TOTAL
Atmospheric Science	—	1	—	1
Biology	115	1	27	143
Undesignated	21	—	—	21
Brain and Cognitive Sciences	25	2	6	33
Chemistry	34	—	22	56
Climate Physics and Chemistry	—	2	—	2
Earth and Planetary Sciences	—	2	—	2
Earth, Atmospheric, and Planetary Sciences	10	—	9	19
Geosystems	—	7	—	7
Mathematics	88	2	16	106
Mathematics with Computer Science	10	—	—	10
Physics	36	9	39	84
Total	339	26	119	484

Appendix C

Fact-Book ETHZ

This appendix contains information relating to (i) faculty and staff, and (ii) students and degrees. Further information is available under the address of ETHZ's Office of Information Management and Controlling[1].

C.1 Faculty and Staff

The section contains the following two tables:

- ETHZ, Categories of Personnel (Table C.1).
- ETHZ, Number of Employees, by *Fachbereich* (Table C.2).

Table C.1: ETHZ, Categories of Personnel

Faculty Full Professors (*ordentliche Professoren*), Associate Professors (*ausserodentliche Professoren*), Assistant Professors (*Assistenzprofessoren*).

Academic Staff Oberassistenten, Other Employment with corresponding educational background.

Research Staff Assistenten und permanent wissenschaftliche Mitarbeiter, Hilfsassistierende.

Administrative Staff Technisches und administratives Personal.

[1] `www.imc.ethz.ch/`.

Table C.2: ETHZ, FACULTY AND STAFF: Number of Employees, by School (*Fachbereich*) (Yearly [rounded] Averages 1998-2000), based on Information supplied by the Office of Information Management and Controlling (IMC). The statistics include 53 doctoral research positions financed by outside sources (not administered by ETHZ).

		Staff:			
SCHOOLS (FACHBEREICHE):	Faculty	Academic	Research	Administrative Technical	TOTAL
Construction & Geomatics	56	62	591	142	851
Engineering Sciences	90	65	1,131	252	1,537
Natural Sciences & Mathematics	102	86	1,158	344	1,689
System-Oriented Sciences	71	117	966	251	1,405
Other Sciences	24	7	180	38	249
TOTAL ACADEMIC	342	337	4,026	1,026	5,731
other Employment	4	448	—	763	1,215
TOTAL ETHZ	346	785	4,026	1,789	6,946

C.2 Students and Degrees

The section contains two further tables:

- ETHZ, Number of Students, by Level and *Fachbereich* (Table C.3).
- ETHZ, Number of Degrees Awarded, by *Fachbereich* (Table C.4).

Table C.3: ETHZ, STUDENTS: Number of 'Diplomstudierende', 'Nachdiplomstudierende' and 'Doktoranden', by School (Fachbereiche) (Yearly [rounded] Averages 1998-2000), based on `www.imc.ethz.ch/stud/`.

SCHOOLS (FACHBEREICHE):	Diplom-Studium	NDS	Doktorat	TOTAL
Construction & Geomatics	1,892	69	193	2,155
Engineering Sciences	2,753	181	688	3,621
Natural Sciences & Mathematics	1,836	21	800	2,657
System-Oriented Sciences	1,859	21	598	2,478
Other Sciences	760	19	—	779
TOTAL	9,100	310	2,279	11,689

Table C.4: ETHZ, TOTAL NUMBER OF DEGREES AWARDED, by School (*Fachbereich*) (Yearly [rounded] Averages 1998-2000).

SCHOOL (*Fachbereich*):	Diplom	Nach-Diplom	Doktorat
Construction & Geomatics	362	46	26
Engineering Sciences	325	79	134
Natural Sciences & Mathematics	257	11	201
System-Oriented Scienses	296	16	136
Other Science	—	15	—
TOTAL	1,240	166	497

Appendix D

Output Indicators

The appendix assembles source material relating to (i) bibliometric indicators as well as (ii) prizes and honors. Regarding the first topic, material of two sources are being presented: material collated by the US National Research Council, and data provided by CEST. With respect to the second topic we present data relating to three awards: the Nobel prize, the Kyoto prize, and the Fields medal.

D.1 Bibliometric Indicators

D.1.1 Research Doctorate Programs of the US

The following tables are being presented:

- Research-Doctorate Programs in the US, National Rang of MIT, by Program (Table D.1).
- Output-Indicators of Research Doctorate Programs in Biomedical Engineering (Table D.2).
- Output-Indicators of Research Doctorate Programs in Chemical Engineering (Table D.3).
- Output-Indicators of Research Doctorate Programs in Civil Engineering (Table D.4).
- Output-Indicators of Research Doctorate Programs in Electrical Engineering (Table D.5).
- Output-Indicators of Research Doctorate Programs in Chemistry (Table D.6).
- Output-Indicators of Research Doctorate Programs in Physics (Table D.7).
- Output-Indicators of Research Doctorate Programs in Molecular Biology (Table D.8).

- Output-Indicators of Research Doctorate Programs in Mathematics (Table D.9).

Table D.1: Research-Doctorate-Programs in the United States (Period 1988-92), National Rank of MIT, by Program, based on [164].

Program	Rank	Table	Page
Linguistics	1	J-7	p. 266
Philosophy	10	J-9	p. 271
Aerospace Engineering	2	K-1	p. 282
Biomedical Engineering	1	K-2	p. 284
Chemical Engineering	2	K-3	p. 286
Civil Engineering	1	K-4	p. 290
Electrical Engineering	2	K-5	p. 295
Materials Science	1	K-7	p. 302
Mechanical Engineering	2	K-8	p. 305
Astrophysics & Astronomy	8	L-1	p. 314
Chemistry	5	L-2	p. 316
Computer Sciences	2	L-3	p. 323
Geociences	2	L-4	p. 328
Mathematics	3	L-5	p. 332
Oceanography	2	L-6	p. 338
Physics	3	L-7	p. 340
Biochemistry & Molecular Biology	2	N-1	p. 386
Cell & Developmental Biology	1	N-2	p. 394
Molecular & General Genetics	1	N-4	p. 406
Neurosciences	14	N-5	p. 410
Pharmacology	11	N-6	p. 415
Economics	3	M-2	p. 355
Political Science	12	M-5	p. 366

Table D.2: OUTPUT-INDICATORS OF RESEARCH DOCTORATE PROGRAMS IN BIOMEDICAL ENGINEERING (Rating of Program [Scale 0 to 5], Number of Faculty, Number of Publications per Faculty, and Number of Citations per Faculty): by Institution (Population Quarters), Period 1988-92, based on [164], Table K-2 (pp. 284).

INSTITUTION (QUARTER)	Rating	Faculty (numbers)	Publications/ Faculty	Citations/ Faculty
MIT	4.6	68	13.0	71.9
University of California (San Diego)	4.5	18	9.4	34.4
University of Washington	4.4	34	9.9	41.1
Duke University	4.3	28	8.5	31.3
University of Pennsylvania	4.3	54	9.8	41.9
Johns Hopkins University	4.3	20	9.5	43.3
University of California (San Francisco)	4.2	42	19.5	100.1
University of California (Berkeley)	4.1	27	12.1	49.0
University of Utah	4.0	67	6.8	22.5
Mean Values Top Quarter (N=9)	4.3	39.8	10.9	48.4
Mean Values 2nd Quarter (N=9)	3.7	26.6	9.9	40.9
Mean Values 3rd Quarter (N=10)	3.3	25.8	6.9	18.9
Mean Values 4th Quarter (N=10)	2.5	10.4	3.8	8.9

Table D.3: OUTPUT-INDICATORS OF RESEARCH DOCTORATE PROGRAMS IN CHEMICAL ENGINEERING (Rating of Program [Scale 0 to 5], Number of Faculty, Number of Publications per Faculty, and Number of Citations per Faculty): by Institution (Population Quarters), Period 1988-92, based on [164], Table K-3 (pp. 286).

INSTITUTION (QUARTER)	Rating	Faculty (numbers)	Publications/ Faculty	Citations/ Faculty
University of Minnesota	4.9	32	23.0	117.2
MIT	4.7	31	18.8	78.6
University of California (Berkeley)	4.6	19	19.5	89.3
University of Wisconsin (Madison)	4.6	19	13.2	32.1
University of Illinois (Urbana)	4.4	15	12.6	45.7
California Institute of Technology	4.4	10	17.7	67.1
Stanford University	4.4	10	20.3	103.9
University of Delaware	4.3	20	12.6	43.7
Princeton University	4.1	15	10.3	43.7
University of Texas (Austin)	4.1	30	18.8	95.8
University of Pennsylvania	4.0	16	12.0	45.2
Carnegie Mellon University	3.9	17	8.2	21.2
Mean Values Top Quarter (N=23)	4.0	18.9	12.4	48.5
Mean Values 2nd Quarter (N=23)	2.9	14.1	9.4	30.0
Mean Values 3rd Quarter (N=23)	2.3	12.4	6.7	15.8
Mean Values 4th Quarter (N=24)	1.7	9.2	4.2	8.5

Table D.4: OUTPUT-INDICATORS OF RESEARCH DOCTORATE PROGRAMS IN CIVIL ENGINEERING (Rating of Program [Scale 0 to 5], Number of Faculty, Number of Publications per Faculty, and Number of Citations per Faculty): by Institution (Population Quarters), Period 1988-92, based on [164], Table K-4 (pp. 290).

INSTITUTION (QUARTER)	Rating	Faculty (numbers)	Publications/ Faculty	Citations/ Faculty
MIT	4.6	40	6.1	25.9
University of California (Berkeley)	4.6	43	6.3	14.7
Stanford University	4.4	23	6.7	23.0
University of Texas (Austin)	4.4	93	5.1	15.1
University of Illinois (Urbana)	4.4	71	2.6	5.5
Cornell University	4.3	33	6.5	13.7
California Institute of Technology	4.3	12	7.6	34.1
Princeton University	4.0	21	6.2	14.2
Northwestern University	4.0	25	13.8	23.8
University of Michigan	3.9	23	5.9	10.6
Purdue University	3.9	56	3.0	2.2
Carnegie Mellon University	3.9	17	5.1	8.7
Mean Values Top Quarter (N=21)	3.9	36.0	4.9	11.9
Mean Values 2nd Quarter (N=22)	3.1	20.6	4.1	6.6
Mean Values 3rd Quarter (N=21)	2.6	16.9	3.2	5.3
Mean Values 4th Quarter (N=22)	1.9	12.7	2.0	2.0

Table D.5: OUTPUT-INDICATORS OF RESEARCH DOCTORATE PROGRAMS IN ELECTRICAL ENGINEERING (Rating of Program [Scale 0 to 5], Number of Faculty, Number of Publications per Faculty, and Number of Citations per Faculty): by Institution (Population Quarters), Period 1988-92, based on [164], Table K-5 (pp. 295).

INSTITUTION (QUARTER)	Rating	Faculty (numbers)	Publications/ Faculty	Citations/ Faculty
Stanford University	4.8	45	17.3	80.1
MIT	4.8	72	10.8	57.6
University of Illinois (Urbana)	4.7	93	13.8	44.4
University of California (Berkeley)	4.7	54	12.6	48.9
California Institute of Technology	4.5	15	16.8	93.5
University of Michigan	4.4	64	11.7	29.5
Cornell University	4.4	47	9.1	33.4
Purdue University	4.0	59	9.2	28.0
Princeton University	4.0	21	15.6	91.1
University of Southern California	4.0	39	5.8	12.1
University of California (Los Angeles)	4.0	50	8.7	24.7
Carnegie Mellon University	3.9	38	8.2	15.9
Mean Values Top Quarter (N=32)	3.8	45.9	8.9	30.9
Mean Values 2nd Quarter (N=29)	2.9	25.9	5.7	16.1
Mean Values 3rd Quarter (N=33)	2.4	22.9	3.1	4.6
Mean Values 4th Quarter (N=32)	1.5	14.7	2.5	3.7

Table D.6: OUTPUT-INDICATORS OF RESEARCH DOCTORATE PROGRAMS IN CHEMISTRY (Rating of Program [Scale 0 to 5], Number of Faculty, Number of Publications per Faculty, and Number of Citations per Faculty): by Institution (Population Quarters), Period 1988-92, based on [164], Table L-2 (pp. 316).

INSTITUTION (QUARTER)	Rating	Faculty (numbers)	Publications/ Faculty	Citations/ Faculty
University of California (Berkeley)	5.0	45	22.3	187.0
California Institute of Technology	4.9	25	18.5	200.1
Harvard University	4.9	20	32.1	362.6
Stanford University	4.9	21	25.2	172.8
MIT	4.9	36	18.8	168.4
Cornell University	4.6	33	19.8	124.2
Columbia University	4.5	17	20.0	147.3
University of Illinois (Urbana)	4.5	44	15.7	89.3
University of Wisconsin (Madison)	4.5	42	10.4	54.5
University of Chicago	4.5	30	17.6	143.0
University of California (Los Angeles)	4.5	52	16.2	163.8
Yale University	4.4	22	17.5	165.5
Mean Values Top Quarter (N=42)	4.0	33.1	16.6	118.2
Mean Values 2nd Quarter (N=42)	2.9	26.6	11.4	52.8
Mean Values 3rd Quarter (N=40)	2.2	18.9	8.4	31.8
Mean Values 4th Quarter (N=44)	1.4	14.1	5.7	20.5

Table D.7: OUTPUT-INDICATORS OF RESEARCH DOCTORATE PROGRAMS IN PHYSICS (Rating of Program [Scale 0 to 5], Number of Faculty, Number of Publications per Faculty, and Number of Citations per Faculty): by Institution (Population Quarters), Period 1988-92, based on [164], Table L-7 (pp. 340).

INSTITUTION (QUARTER)	Rating	Faculty (numbers)	Publications/ Faculty	Citations/ Faculty
Harvard University	4.9	32	15.6	170.7
Princeton University	4.9	47	7.8	110.0
MIT	4.9	83	11.3	121.2
University of California (Berkeley)	4.9	67	13.4	84.7
California Institute of Technology	4.8	39	10.5	116.1
Cornell University	4.8	54	9.2	69.6
University of Chicago	4.7	40	10.4	84.2
University of Illinois (Urbana)	4.7	98	13.7	86.2
Stanford University	4.5	25	8.4	73.8
University of California (Santa Barbara)	4.4	45	14.2	178.1
University of Texas (Austin)	4.3	85	10.4	60.4
Columbia University	4.3	34	8.1	68.6
Mean Values Top Quarter (N=36)	4.0	49.1	9.8	71.5
Mean Values 2nd Quarter (N=37)	3.1	32.2	8.7	47.6
Mean Values 3rd Quarter (N=37)	2.5	21.7	7.1	31.1
Mean Values 4th Quarter (N=37)	1.7	14.2	5.8	23.9

Table D.8: OUTPUT-INDICATORS OF RESEARCH DOCTORATE PROGRAMS IN BIOCHEMISTRY AND MOLECULAR BIOLOGY (Rating of Program [Scale 0 to 5], Number of Faculty, Number of Publications per Faculty, and Number of Citations per Faculty): by Institution (Population Quarters), Period 1988-92, based on [164], Table N-1 (pp. 386).

INSTITUTION (QUARTER)	Rating	Faculty (numbers)	Publications/ Faculty	Citations/ Faculty
University of California (San Francisco)	4.8	45	17.3	463.9
MIT	4.8	54	19.4	421.5
Stanford University	4.8	14	15.4	350.5
University of California (Berkeley)	4.8	34	17.9	360.8
Harvard University	4.8	14	21.31	584.0
Yale University	4.6	33	13.9	205.2
California Institute of Technology	4.6	30	16.7	270.7
University of Wisconsin (Madison)	4.6	173	10.8	104.2
University of California (San Diego)	4.5	142	16.0	272.2
Johns Hopkins University	4.4	56	10.2	112.3
Columbia University	4.4	62	11.9	198.6
University of Colorado	4.3	34	9.2	118.7
Mean Values Top Quarter (N=48)	3.9	59.8	11.9	158.7
Mean Values 2nd Quarter (N=49)	2.9	31.1	8.3	68.2
Mean Values 3rd Quarter (N=48)	2.3	22.9	5.8	32.0
Mean Values 4th Quarter (N=49)	1.3	10.7	4.6	22.8

Table D.9: OUTPUT-INDICATORS OF RESEARCH DOCTORATE PROGRAMS IN MATHEMATICS (Rating of Program [Scale 0 to 5], Number of Faculty, Number of Publications per Faculty, and Number of Citations per Faculty): by Institution (Population Quarters), Period 1988-92, based on [164], Table L-5 (pp. 332).

INSTITUTION (QUARTER)	Rating	Faculty (numbers)	Publications/ Faculty	Citations/ Faculty
University of California (Berkeley)	4.9	58	4.2	10.5
Princeton University	4.9	37	4.4	24.5
MIT	4.9	46	5.0	15.0
Harvard University	4.9	27	4.6	21.3
University of Chicago	4.7	58	2.9	10.7
Stanford University	4.7	24	7.0	23.1
Yale University	4.6	32	3.8	9.1
New York University	4.5	46	7.2	20.8
University of Michigan	4.2	51	4.0	9.7
Columbia University	4.2	13	3.8	14.5
California Institute of Technology	4.2	13	5.8	11.8
University of California (Los Angeles)	4.1	84	5.5	16.0
Mean Values Top Quarter (N=33)	4.1	45.9	4.5	11.9
Mean Values 2nd Quarter (N=35)	3.1	33.7	3.7	7.1
Mean Values 3rd Quarter (N=36)	2.4	28.9	3.9	4.2
Mean Values 4th Quarter (N=35)	1.5	20.0	2.7	3.9

D.1.2 CEST Data

The section presents the following tables:

- MIT and ETHZ, Total Publication, by Institution and Field (Table D.10).
- MIT and ETHZ, Total Publication, by Institution and Subfield (Table D.11).
- MIT and ETHZ, Number of Fields (or Subfields) Sustained (Table D.12).
- MIT and ETHZ, Relative Citation Index (RCI), by Institution and Field (Table D.13).
- MIT and ETHZ, Relative Citation Index (RCI), by Institution and Subfield (Table D.14).

Table D.10: MIT AND ETHZ, TOTAL PUBLICATIONS: by Institution and Field (i.e. Journal Categories), Annual Means 1994-99, based on [35] ("*" indicates that there are less than 50 publications in 6 years, and "—" stands for zero publications).

CODE	FIELDS:	MIT	ETHZ
f01	Multidisciplinary	261	43
f02	Agricultural Sciences	*	33
f03	Engineering	360	153
f04	Materials Science	83	28
f05	Computer Science	88	13
f06	Mathematics	77	40
f07	Physics	817	433
f08	Astrophysics	158	33
f09	Geosciences	148	128
f10	Chemistry	336	391
f11	Plant & Animal Science	25	92
f12	Biology & Biochemistry	200	149
f13	Ecology & Environment	20	45
f14	Microbiology	37	47
f15	Molecular Biology & Genetics	198	61
f16	Neuroscience	79	60
f17	Immunology	28	—
f18	Pharmacology	28	30
f19	Clinical Medicine	163	43
f20	Psychology & Psychiatry	23	*
f21	Social Sciences	58	*
f22	Education	*	—
f23	Economics & Business	126	*
f24	Law	*	—
f25	Arts & Humanities	50	*

Table D.11: MIT AND ETHZ, TOTAL PUBLICATIONS: by Institution and Subfield (i.e. Journal Categories), Annual Means 1994-99, based on [35] ("*" indicates that there are less than 50 publications in 6 years).

CODE	SUBFIELDS:	MIT	ETHZ
f01_01	Agriculture, Biology & Environmental Sciences	35	*
f01_02	Life Sciences	187	26
f01_03	Physical, Chemical & Earth Sciences	42	11
f02_02	Agriculture & Agronomy	*	13
f02_03	Food Science & Nutrition	*	13
f03_01	AI, Robotics & Automatic Control	55	9
f03_02	Aerospace Engineering	21	*
f03_03	Civil Engineering	20	11
f03_04	Electrical & Electronic Engineering	80	33
f03_05	Engineering Management, General Engineering	17	*
f03_06	Engineering Mathematics	28	*
f03_07	Environmental Engineering & Energy	15	*
f03_08	Instumentation & Measurement	21	19
f03_09	Mechanical Engineering	49	14
f03_10	Nuclear Engineering	19	*
f03_11	Spectroscopy, Instrumentation, Analytical Sciences	34	51
f04_01	Material Science & Engineering	58	26
f04_02	Metallurgy	25	*
f05_01	Computer Science & Engineering	61	*
f05_03	Information Technology & Communications Systems	26	*
f07_01	Optics & Acoustics	52	22
f07_02	Applied Physics, Condensed Matter, Materials Science	324	240
f07_03	Nuclear-, Particle-, Theoretical- and Plasma-Physics	442	171
f09_02	Earth Sciences	146	126
f10_01	Chemical Engineering	26	37
f10_02	Chemistry & Analysis	52	50
f10_03	Chemistry	54	88
f10_04	Inorganic & Nuclear Chemistry	17	25
f10_05	Organic Chemistry & Polymer Science	67	44
f10_06	Physical Chemistry & Chemical Physics	122	147
f11_01	Animal Sciences	*	15
f11_02	Aquatic Sciences	15	*
f11_03	Entomology, Pest Control	*	9
f11_04	Plant Sciences	*	42
f11_06	Animal & Plant Science	*	17
f12_01	Biology	*	10
f12_02	Biochemistry & Applied Microbiology	19	15
f12_03	Biochemistry & Biophysics	151	108
f12_04	Endocrinology, Nutrition & Metabolism	13	*
f15_01	Cell & Developmental Biology	113	22
f15_02	Molecular Biology & Genetics	85	39
f19_26	Cardiovascular & Hematology Research	15	*
f19_27	Medical Research, Diagnosis & Treatment	12	*
f19_28	Medical Research, General Topics	22	*
f19_29	Medical Research, Organs & Systems	29	*
f19_30	Oncogenesis & Cancer Research	18	*
f21_04	Political Science & Public Administration	27	*
f23_01	Economics	89	*
f23_02	Management	36	*
f25_06	History	12	*
f25_07	Language & Linguistics	14	*

Table D.12: MIT and ETHZ, Number of Fields (or Subfields) Sustained: by minimum Number of Publications per annum and by Institution, Annual Means 1994-99, based on [35].

Publications per annum (min)	Fields (Subfields) Sustained: MIT	ETHZ
10	48	35
20	39	25
30	28	19
40	24	14
50	22	9
60	16	7
70	14	6
80	12	6
90	9	5
100	9	5
110	9	4
120	8	3
130	7	3
140	7	3
150	6	2
160	4	2
170	3	2
180	3	1
190	2	1
200	2	1
240	2	1
320	2	0
440	1	0

Table D.13: MIT AND ETHZ, RELATIVE CITATION INDEX (RCI): by Institution and Field (i.e. Journal Categories), Annual Means 1994-99, based on [35] ("*" indicates that there are less than 50 publications in 6 years, and "—" stands for zero publications; in both cases, the RCI has not been computed).

CODE	FIELDS:	MIT	ETHZ
f01	Multidisciplinary	44	32
f02	Agricultural Sciences	*	–3
f03	Engineering	33	19
f04	Materials Science	51	41
f05	Computer Science	39	12
f06	Mathematics	46	24
f07	Physics	52	26
f08	Astrophysics	40	9
f09	Geosciences	34	13
f10	Chemistry	47	33
f11	Plant & Animal Science	41	18
f12	Biology & Biochemistry	41	17
f13	Ecology & Environment	58	25
f14	Microbiology	23	0
f15	Molecular Biology & Genetics	79	29
f16	Neurosccience	48	–6
f17	Immunology	56	—
f18	Pharmacology	47	32
f19	Clinical Medicine	60	–28
f20	Psychology & Psychiatry	68	*
f21	Social Sciences	10	*
f22	Education	*	—
f23	Economics & Business	82	*
f24	Law	*	—
f25	Arts & Humanities	87	*

Table D.14: MIT AND ETHZ, RELATIVE CITATION INDEX (RCI): by Institution and Subfield (i.e. Journal Categories), Annual Means 1994-99, based on [35] ("*" indicates that there are less than 50 publications in 6 years, in which case the RCI has not been computed).

CODE	SUBFIELDS:	MIT	ETHZ
f01_01	Agriculture, Biology & Environmental Sciences	53	*
f01_02	Life Sciences	28	23
f01_03	Physical, Chemical & Earth Sciences	62	38
f02_02	Agriculture & Agronomy	*	19
f02_03	Food Science & Nutrition	*	–34
f03_01	AI, Robotics & Automatic Control	62	44
f03_02	Aerospace Engineering	8	*
f03_03	Civil Engineering	52	50
f03_04	Electrical & Electronic Engineering	56	1
f03_05	Engineering Management, General Engineering	–52	*
f03_06	Engineering Mathematics	42	*
f03_07	Environmental Engineering & Energy	38	*
f03_08	Instumentation & Measurement	21	33
f03_09	Mechanical Engineering	43	–17
f03_10	Nuclear Engineering	56	*
f03_11	Spectroscopy, Instrumentation, Analytical Sciences	24	31
f04_01	Material Science & Engineering	50	32
f04_02	Metallurgy	55	*
f05_01	Computer Science & Engineering	45	*
f05_03	Information Technology & Communications Systems	38	*
f07_01	Optics & Acoustics	46	54
f07_02	Applied Physics, Condensed Matter, Materials Science	50	30
f07_03	Nuclear-, Particle-, Theoretical- and Plasma-Physics	53	25
f09_02	Earth Sciences	32	11
f10_01	Chemical Engineering	33	35
f10_02	Chemistry & Analysis	40	29
f10_03	Chemistry	67	38
f10_04	Inorganic & Nuclear Chemistry	66	25
f10_05	Organic Chemistry & Polymer Science	30	38
f10_06	Physical Chemistry & Chemical Physics	33	31
f11_01	Animal Sciences	*	–26
f11_02	Aquatic Sciences	44	*
f11_03	Entomology, Pest Control	*	–51
f11_04	Plant Sciences	*	30
f11_06	Animal & Plant Science	*	34
f12_01	Biology	*	27
f12_02	Biochemistry & Applied Microbiology	34	21
f12_03	Biochemistry & Biophysics	49	18
f12_04	Endocrinology, Nutrition & Metabolism	53	*
f15_01	Cell & Developmental Biology	77	11
f15_02	Molecular Biology & Genetics	77	40
f19_26	Cardiovascular & Hematology Research	30	*
f19_27	Medical Research, Diagnosis & Treatment	37	*
f19_28	Medical Research, General Topics	25	*
f19_29	Medical Research, Organs & Systems	46	*
f19_30	Oncogenesis & Cancer Research	11	*
f21_04	Political Science & Public Administration	66	*
f23_01	Economics	83	*
f23_02	Management	79	*
f25_06	History	57	*
f25_07	Language & Linguistics	94	*

D.2 Prizes and Honors

D.2.1 Nobel Prize

The section presents the following tables:

- Nobel Prizes (Nobelists) in Chemistry, by Institution (Table D.15).
- Nobel Prizes (Nobelists) in Chemistry, by US-Institution (Table D.16).
- Nobel Prizes (Nobelists) in Physics, by Institution (Table D.17).
- Nobel Prizes (Nobelists) in Physics, by US-Institution (Table D.18).
- Nobel Prizes (Nobelists) in Physiology or Medicine, by Institution (Table D.19).
- Nobel Prizes (Nobelists) in Physiology or Medicine, by US-Institution (Table D.20).
- Nobel Prizes (Nobelists) in Economics, by Institution (Table D.21).
- Nobel Prizes (Nobelists) in Economics, by US-Institution (Table D.22).

Table D.15: NOBEL PRIZES (NOBELISTS) IN CHEMISTRY, by Nation and Institution (1945-2001; for US-Nobelists, see Table D.16).

NATION	INSTITUTION	YEARS
AR	Institute for Biochemical Research, Buenos Aires	1970
B	Université Libre de Bruxelles	1977
CA	National Research Council, Ottawa	1971
	University of British Columbia	1993
	University of Toronto	1986
CZ	Czechoslovak Academy of Science, Prague	1959
CH	ETHZ	1991, 1975
D	Max-Planck Institut, Göttingen	1967
	Max-Planck Institut, Mainz	1995
	Max-Planck Institut, Martinsried	1988
	Max-Planck Institut, Mühlheim	1963
	Max-Planck Institut, Frankfurt/Main	1988
	Technische Universität München	1973
	Universiät Freiburg	1953
	Universiät Heidelberg	1979
	Universiät Kiel	1950
	Universiät Köln	1950
DK	Aarhus University	1997
F	Université Strasbourg/Collège de France, Paris	1987
FIN	Helsinki University	1945
I	Institute of Technology, Milan	1963
JP	Kyoto University	1981
	Nagoya University	2001
	University of Tsukuba	2000
NO	Oslo University	1969
S	Uppsala University	1948
SU	Academy of Sciences, Moscow	1956
UK	Glynn Research Laboratories	1978
	Imperial College	1973, 1969
	National Institute for Medical Research, London	1952
	Oxford University	1964, 1956, 1947
	Rowett Research Institute, Scotland	1952
	Royal Institution of Great Britain, London	1967
	University of Cambridge	1997, 1982, 1980, 1967 1962(2), 1958, 1957
	University of Sussex	1996, 1975

Table D.16: NOBEL PRIZES (NOBELISTS) IN CHEMISTRY, by US-Institution (1945-2001).

INSTITUTION	YEARS
Biological Laboratories, Cambridge	1980
California Institute of Technology	1999, 1992, 1954
Cetus	1993
Cornell University	1981, 1955, 1946
Du Pont	1987
Harvard University	1990, 1986, 1976, 1965
Medical Foundation of Buffelo	1985
MIT	1995
Monsanto	2001
National Institutes of Health, Bethesda	1972
Northwestern University	1998
Purdue University	1979
Rockefeller Institute for Medical Research, Princeton	1946
Rockefeller University	1984, 1972(2)
Rice University	1996(2)
Scripps Research Institute	2001
Stanford University	1983, 1980, 1974
University of California, Berkeley	1986, 1961, 1951(2), 1949
University of California, Irvine	1995
University of California, Los Angeles	1997, 1987, 1960
University of California, Santa Barbara	2000, 1998
University of Chicago	1966
University of Colorado	1989
University of Pennsylvania	2000
University of Southern California	1994
University of Texas, Dallas	1988
US Navel Research Laboratory	1985
Yale University	1989, 1968

Table D.17: NOBEL PRIZES (NOBELISTS) IN PHYSICS, by Nation and Institution (1945-2001; for US-Nobelists, see Table D.18.)

NATION	INSTITUTION	YEARS
CA	McMaster University	1994
CH	CERN	1992, 1988, 1984(2), 1976
	IBM Research Laboratory	1987(2), 1986(2)
D	Max-Planck Institut, Berlin	1986
	Max-Planck Institut, Stuttgart	1985
	Universität Bonn	1989
	Universität Heidelberg	1963, 1954
	Technische Hochschule München	1961
DK	Niels Bohr Institute, Copenhagen	1975
	Nordita, Copenhagen	1975
I	International Centre for Theoretical Physics, Trieste	1979
NL	Groningen University	1953
	Utrecht University	1999
F	Collĝe de France/Ecole Normale Supérieure, Paris	1997, 1992, 1991, 1966
	Universit'e de Grenoble	1970
JP	Kyoto Imperial University	1949
	Tokyo University	1965
RU, SU	Academy of Sciences, Moscow	1978, 1962, 1958(3)
	Lebedev Institute of Physics, Moscow	1964
	Physico-Technical Institute, St. Petersburg	2000
S	Uppsala University	1981
	Royal Institute of Technology	1970
UK	Atomic Energy Reserach Establishment	1951
	Bristol University	1950
	Cambridge University	1977, 1974(2), 1973
	Department of Scientific & Industrial Research, London	1947
	Dublin University	1951
	Edinburgh University	1954
	Imperial College	1979, 1971
	Victoria University, Manchester	1948

Table D.18: NOBEL PRIZES (NOBELISTS) IN PHYSICS, by US-Institution (1945-2001).

INSTITUTION	YEARS
Beckman Instruments	1956
Bell Laboratories	1978(2), 1977, 1956
Brown University	1972
California Institute of Technology	1983, 1969, 1965, 1961
Columbia University	1998, 1975, 1957, 1955, 1949
Cornell University	1996(2), 1982, 1967
Digital Pathways	1988
Fermi National Accelerator Laboratory	1988
General Electric	1973
Harvard University	1989, 1981, 1979(2), 1977 1965, 1952, 1946
IBM Research Center, Yorktown Hights	1973
MIT	2001, 1994, 1990(2), 1976, 1964
National Institute of Standards & Technology, Boulder	2001
National Institute of Standards & Technology, Gaithersburg	1997
Princeton University	1998, 1993(2), 1980, 1963 1957, 1945
Stanford University	1998, 1997, 1996, 1995, 1990 1981, 1976, 1961, 1955, 1952
Texas Instruments	2000
University of California, Berkeley	1968, 1960, 1959(2)
University of California, Irvine	1995
University of California, La Jolla	1963
University of California, Santa Barbara	2000
University of Chicago	1983, 1980
University of Colorado	2001
University of Illinois	1972, 1956
University of Pennsylvania	1972
University of Michigan	2000
University of Washington	1989

Table D.19: NOBEL PRIZES (NOBELISTS) IN PHYSIOLOGY OR MEDICINE, by Nation and Institution (1945-2001; for US-Nobelists, see Table D.20).

NATION	INSTITUTION	YEARS
A	Institut für Verhaltensforschung (Altenberg)	1973
AR	Institute for Biology and Experimental Medicine (Buenos Aires)	1947
AU	Australian National University (Canberra)	1963
	Walter and Eliza Hall Institute (Melbourne)	1960
B	Université Cathoique de Louvain	1974
CH	Basel Institute of Immunology	1984(2)
	Geigy	1948
	University of Basel	1978, 1950
	University of Zürich	1996, 1949
D	Max-Planck-Institut für Biophysikalische Chemie (Göttingen)	1991
	Max-Planck-Institut für Medizinische Forschung (Heidelberg)	1991
	Max-Planck-Institut für Zellchemie (München)	1964
	Max-Planck-Institut für Entwicklungsbiologie (Tübingen)	1995
	Universität Mainz	1956
	Universität München	1973
F	Institut Pasteur (Paris)	1965(3)
F	Université de Paris	1980
IT	Institute of Cell Biology of the CNR (Rome)	1986
	Institute of Public Health (Rome)	1957
P	University of Lisbon	1949
S	Göteborg University	2000
	Nobel Medical Institute Stockholm	1955
	Karolinska Institute (Stockholm)	1982(2), 1970, 1967
UK	Central Research Laboratories (EMI, London)	1979
	Imperial Cancer Research Fund Laboratory (London)	2001(2), 1975
	Sheffield University	1953
	University of Cambridge	1984, 1963, 1962
	University of London	1988, 1970, 1963
		1962, 1960, 1945
	University of Oxford	1973, 1972, 1945(2)
	Wellcome Research Laboratories (Beckenham)	1982

Table D.20: NOBEL PRIZES (NOBELISTS) IN PHYSIOLOGY OR MEDICINE, by US-Institution (1945-2001).

INSTITUTION	YEARS
Bringham and Women's Hospital (Boston)	1990
California Institute of Technology	1995, 1981, 1969, 1958
Carnegie Institution of Washington (Long Island, NY)	1969
Children's Medical Center (Boston)	1954
Cold Spring Harbor Laboratory (NY)	1983
Columbia University	2000, 1956(2)
Cornell University	1968
Fred Hutchinson Cancer Research Center (Seattle)	1990
Harvard University	1981(2), 1980, 1967, 1964
	1962, 1962, 1954, 1953
Indiana University	1946
Institute for Cancer Research (Philadelphia)	1976
Jackson Laboratory (Bar Harbor, ME)	1980
Johns Hopkins University	1978(2)
Mayo Clinic (Rochester)	1950(2)
MIT	1993, 1987, 1975, 1969
National Institute of Environmental Health (Bethesda, MD)	1976, 1970, 1968
National Institute of Environmental Health Sciences (NC)	1994
New England Biolabs	1993
New York University	1959
Princeton University	1995
Rockefeller University	2000, 1999, 1974, 1972
	1967, 1966, 1958, 1951
Rutgers University	1952
Salk Insitute (San Diego)	1977
St. Jude Children's Research Hospital (Memphis)	1996
Stanford University	1959
State University of New York	1998
University of California (Los Angeles)	1998
University of California (San Francisco)	1997, 1989(2)
University of Chicago	1966
University of Texas (Dallas)	1998, 1994, 1985(2)
University of Washington	2001, 1992(2)
University of Wisconsin	1975, 1968, 1958
Tufts University	1979
Vanderbilt University	1986, 1971
Veterans Administration Hospital (Bronx)	1977
Veterans Administration Hospital (New Orleans)	1977
Washington University (St. Louis)	1947(2)
Wellcome Research Laboratories (Research Triangle Park, NC)	1988(2)
Western Reserve University	1954
Yale University	1974

Table D.21: NOBEL PRIZES (NOBELISTS) IN ECONOMICS, by Nation and Institution (1945-2001; for US-Nobelists, see Table D.22).

NATION	INSTITUTION	YEARS
D	Universität Bonn	1994
	Universität Freiburg	1994
F	Ecole Nationale Supérieur des Mines (Paris)	1988
NL	Netherlands School of Economics (Rotterdam)	1969
NO	University of Oslo	1989, 1969
S	Stockholm University	1977, 1974
UK	University of Cambridge	1998, 1996, 1984, 1977
	University of Oxford	1972
SU	Academy of Sciences (Moscow)	1975

Table D.22: NOBEL PRIZES (NOBELISTS) IN ECONOMICS, by US-Institution (1945-2001).

INSTITUTION	YEARS
Carnegie Mellon University	1978
City University of New York	1990
Columbia University	2001, 1999, 1996
George Mason University	1986
Harvard University	1997, 1973, 1972, 1971
MIT	1987, 1985, 1970
Princeton University	1994, 1979
Stanford University	2001, 1997, 1990
University of California (Berkeley)	2001, 2000, 1994, 1983
University of Chicago	2000, 1995, 1993, 1992, 1991, 1990, 1982, 1979, 1976
University of Pennsylvania	1980
Washington University (St. Louis)	1993
Yale University	1981, 1975

D.2.2 Kyoto Prize

Table D.23: KYOTO PRIZES (LAUREATES), by Field (Advanced Technology, and Basic Sciences), Nation and Institution (1985-2001).

NATION	INSTITUTION	Technology	Sciences
CH	Universität Basel	—	2000
	ETHZ	1998	—
F	CNRS	1986	—
J	Engineering Academy of Japan	2001	—
	Kobe University	—	1992
	Kyoto University	—	1998, 1995
	Shima Co., Ltd.	1997	—
NL	Leiden University	—	1987
Tanzania	Gombe Stream Research Center	—	1990
US	BEA Systems, Inc.	1997	—
	Bell Telephone Laboratories	1989	—
	FTI Teklicon, Inc.	1997	—
	MIT	1987	1991, 1988, 1985
	MRC Molecular Genetics Unit	1990	—
	National Academies of Sciences and Engineering	2001	—
	Princeton University	—	1994
	Stanford University	1996, 1988	—
	Synaptics, Inc.	1997	—
	Texas Instruments	1993	—
	University of Arizona	1999	—
	University of California (San Diego)	—	1999
	University of Florida	1985	—
	University of Illinois	1994	—
	University of Pennsylvania	—	1997
	University of Southern California	1991	—
	Yale University	—	1986
	University of Utah	—	1996
RU, SU	Russian Academy of Sciences	2001	—
	University of Moscow	—	1989
UK	Cambridge University	1992	—
	Oxford University	2000	1993
	University of Hull	1995	—
	University of Sussex	—	2001

D.2.3 Fields Medal

Table D.24: FIELDS MEDAL (LAUREATES), by Nation and Institution (1950-1998).

NATION	INSTITUTION	Year
F	CNRS	1994, 1954
	Institut des hautes études scientifiques	1998, 1982, 1978, 1966
F	Ecole Normale Supérieure, Université de Stasbourg	1958
	Université de Nancy	1950
	Université de Paris-Sud (Orsay)	1994
I	University of Pisa	1974
J	Kyoto University	1990
S	University of Stockholm	1962
UK	Cambridge University	1998(2), 1970, 1970
	Oxford University	1986, 1978, 1966
	University College London	1958
US	Harvard University	1998, 1974, 1970
	Princeton University	1998, 1994, 1990
		1986, 1982(2), 1978
		1962, 1954, 1950
	Stanford University	1966
	University of California (Berkeley)	1990, 1966
	University of California (San Diego)	1986
RU, SU	Institute for Problems of Information Transmission	1978
	Moscow University	1970
	Russian Academy of Sciences (Novosibirsk)	1994

Appendix E

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