

Indicators on individual higher education institutions: addressing data problems and comparability issues

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Higher education institutions (HEIs) are crucial to the development of the European Research Area. However, unlike in the USA, the availability of quantitative indicators for individual HEI at the European level is severely limited by several methodological issues, data availability problems and national institutional constraints. The paper discusses strategies for collecting and validating data from different national sources; the limitations of the available data for different categories of indicators and, finally, the influence of the heterogeneity of the national HEIs on comparability at the European level. Based on the experience of two recently completed projects, the paper shows that, despite these problems, it is possible to collect relatively coherent data on European HEIs and to develop a set of consequential indicators. Further, it provides advice on how to exploit them for comparative purposes in a sensible way. It concludes by indicating areas where major improvements are urgently needed, and advocates a European S&T Indicators Platform to maintain and develop these data sets long term.

HIGHER EDUCATION INSTITUTIONS (HEIs) play an important role in the development of the European Research Area. These institutions have been the object of many studies using a variety of approaches (see for example; Neave and Van Vught, 1994; Amaral *et al*, 2002; Ehrenberg, 2004). However, there have been until now limited attempts in the European context to develop indicators at the level of individual institutions and to use them for systematic cross-national comparisons. The choice for higher education studies so far have been between aggregate data at national system level provided by statistical offices, or detailed case-studies data

collected for single or a few HEIs. Studies utilizing national aggregates or data for a few institutions, however, do not reflect the institutional variety in many countries, nor are they open for systematic trans-national comparisons of individual institutions. As a consequence, some of the most important problems in the economics and policy of science and higher education cannot be addressed empirically due to lack of data or poor quality of data or to conceptual problems in defining and measuring suitable indicators (Griliches 1994; Bonaccorsi and Daraio 2004). Moreover, since at national level as well as at European level, policy-makers, institutional leaders and other stakeholders are increasingly considering European higher education as a whole system, comparisons between institutions on a trans-national level are crucially needed for policy and management purposes.

One obvious reason for this has been the non-availability of data. While statistics for the research, education and entrepreneurship part of HEIs have been discussed and developed over many years in the framework of OECD and of Eurostat (OECD 1989, 1992, 2005; Fuller, 2005; Godin, 2005), the aim has mainly been the building of national

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aggregates for the purpose of trans-national comparisons, and data and indicators are usually disseminated as national aggregates without the underlying institutional-level data being made accessible. Typically, statistical publications and indicators reports such as *Education at a Glance* (OECD, 1993–), *Main Science and Technology Indicators* (OECD, 1982–) and the *Third European Report on Science and Technology Indicators* (European Commission, 2003) show a wide variety of indicators, but publication of institutional data and indicators is exceptionally rare (the *Third European Report on Science and Technology Indicators*, 2003, has a few data on number of publications per institution).

Yet, institutional-level data exist in most European countries. They may be provided by some national authority (eg the Swiss Federal Statistical Office, the Higher Education Statistics Agency in the UK and the Norwegian Social Science Data Service in Norway), by rectors conferences (eg in Italy and Spain) or by the individual institution. Hence, the main difficulty is not always data availability, rather the definition of a common data structure incorporating the heterogeneity of national higher education systems and of individual institutions. HEIs are indeed characterized by the complexity of the tasks they perform (eg undergraduate vs. post-graduate level of education, research intensity, combination of scientific fields and disciplines, engagement in third mission activities, etc), as well as in the configuration of the resources available for the performing of these tasks (eg differences in composition of funding sources, staff, availability of PhD students, etc). Further complexities are introduced through variations in internal organization (eg introduction of cross-disciplinary centres of excellence or research units without educational tasks) and in national higher education systems (eg the dual structure of the system in some countries and the federal vs. regional dimension in others).

Within this framework, some newly completed studies have brought considerable progress. The AQUAMETH¹ project collected data on HEIs in six countries in a systematic way by applying broad common definitions of data categories across countries and collecting information already available at national level. The same approach has been reproduced with minor modifications in the CHINC²

project on a sample of more than 100 institutions in 11 countries. Nevertheless, the collection of data and subsequent construction of databases with institutional data, which *per se* represents a very important result of these projects, has to be understood within the proper context. These databases cannot be used in a ‘data mining’ way, but their exploitation needs a profound understanding of the higher education systems data originates from, and the meaning and limitations of the contained data. These needs are due both to conceptual problems and to the data collection procedures. This article has two major aims: to serve as a guide for those interested in further exploiting the collected data and to point out some urgently needed improvements in data availability.

The article is organized as follows. In the second section, we introduce the main definitions and the data structure, as well as the data collection strategy we followed. In the third section, we present the availability of data and discuss main quality and comparability problems. In the fourth section, we discuss how to interpret the produced indicators in different national higher education systems and taking into account the specificities of individual HEIs. The fifth section concludes with some lessons to be drawn concerning the production of institutional-level indicators and their use in a European context.

Conceptual framework and data structure

The conceptual framework of the AQUAMETH and CHINC data structure was built on the following main statements (Bonaccorsi and Daraio, 2007a; see Figure 1):

1. The adoption of the individual HEI as the main level of analysis. Thus despite all the caveats concerning their institutional embeddedness from one side, their loose organization with large autonomy of subunits to the other side, we consider that the university level is (increasingly) relevant also in the European context for strategic decision and profiling and thus that we need indicators at this level (see Bonaccorsi and Daraio, 2007b).
2. Considering HE activity as a multidimensional activity where teaching, research, dissemination, innovation and general contributions to the culture

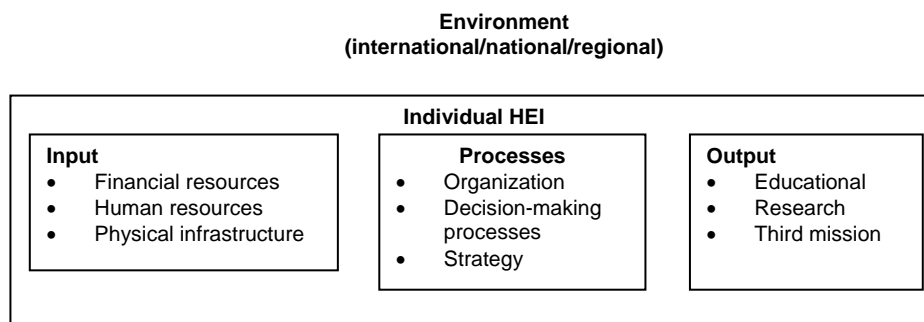


Figure 1. A framework for HEI indicators

- are combined (Slipersæter, 2005). The activity of HEIs is thus based on a multi-input, multi-output relationship in which inputs and outputs are not only qualitatively heterogeneous but sometimes truly incommensurable. Thus, we avoid the separation between R&D and higher education activities which is current in most available statistics (eg concerning expenditures and personnel; OECD, 2002).
- Individual HEIs are embedded in an institutional context, including the structure of the national higher education system, that determines to some extent their framework conditions (eg the available funding sources), as well as their rules for functioning. Thus, contextual information on national systems needs to be introduced at the level of analysis and drawn either from reports by national experts or from existing literature.

From the onset, we notice three relevant features of this framework.

- Dimensions that could be, at least in principle, amenable to quantitative indicators (such as financial resources) go alongside dimensions that are qualitative or that are difficult to operationalize. This, of course, has important consequences on the methodology for collecting data. In CHINC we completed quantitative data with the qualitative information on strategies and governance issues collected through interviews to HEI managers, but further methodological work has to be done concerning the integration between the two types of data (Slipersæter *et al*, 2005).
- There are complex links between the different dimensions, especially between input and output variables (endogeneity). For example, where performance related allocation models are in place, the available financial resources as an input will partly depend on output.
- We notice the possible richness of variations emanating from this approach and the corresponding need for detailed analysis of governance issues if the variations were to be fully understood. However, it is an open question if such a complex approach, which would require individual case studies, is necessary to produce broad comparisons of HEI in different countries. Instead, qualitative information might be introduced at the level of interpretation of results using the expert knowledge of the participating teams.

Variables and definitions

Variables were organized in six broad areas: general information on the HEI; revenues; expenditures; personnel; education production; research and innovation production. The choice of the variables and indicators has been to a large extent a compromise between the model presented and the kind of questions to be addressed in the project from one side, and practical issues of data availability to the other side.

Table 1 presents a detailed list of the variables for each domain. These are not statistical definitions in the strict sense, but rather instructions to the national correspondents on how to fill the forms starting from the information available at national level. Leaving

Table 1. List of variables

Area	Categories
<i>General information</i>	<ul style="list-style-type: none"> • Year of foundation • City, province, region (NUTS) • Number and type of faculties/schools/disciplines covered • Governance (public, private) • Type (university, technical college) • Other relevant historical information
<i>Revenues</i>	<ul style="list-style-type: none"> • Total revenues of the university • General budget of the university (in federal countries divided between national and regional appropriations) • Tuition and fees • Grants and contracts, if possible divided between government, international, private and private non-profit • Other revenues
<i>Expenditures</i>	<ul style="list-style-type: none"> • Total expenditures (excluding investments and capital costs) • Personnel expenditures, if possible divided between personnel categories • Other expenditures
<i>Personnel</i>	<ul style="list-style-type: none"> • Total staff (FTE or headcount) • Professors • Other academic staff • Technical and administrative staff
<i>Education production</i>	<ul style="list-style-type: none"> • Number of undergraduate students • Number of undergraduate degrees • Number of PhD students • Number of PhD degrees
<i>Research and innovation production</i>	<ul style="list-style-type: none"> • Thomson Scientific/ ISI publication data • Innovation production indicators (eg patents, licenses)

some room to national correspondents has been necessary given the differences in the data availability in each country, still with comparability in view.

As is well known in the literature (see eg Hicks, 2004; Nederhof, 2006), quantitative analysis of scientific publications in social sciences and humanities are subject to a series of issues and pitfalls which are related to the organization of scientific activity and to the publication habits in these domains, which impact also on the usability of results drawn from Thomson Scientific/ISI databases (Van Raan, 2004). The main issues are related to the fact that journal articles are not the only important scientific output, but 'other' publications such as books, book chapters and monographs are also significant; the multidisciplinary of social sciences makes it difficult to identify a core set of journals representative for the aggregate output of the domain; and finally, the importance of literature in national languages, which in some fields represents a significant share of publications (Hicks, 1999, 2004) and the overrepresentation of English literature in Thomson Scientific/ISI (Archambault *et al*, 2006). Despite these limitations, Thomson Scientific/ISI databases can be used in some domains of the social sciences (Nederhof, 2006).

Alternatives to Thomson Scientific/ISI are not easy to use. Other corporate databases such as Elsevier SCOPUS share the same limitations, while a number of specialized databases in specialized domains are difficult to use for bibliometric purposes for a number of reasons, mostly because they do not provide the addresses of all authors (Archambault and Vignola Gagné, 2004). Web searches and particularly Google scholar searches provide broader access to open literature, but suffer from major problems of data quality (Jacso, 2005). Finally, compilation of publication lists from CVs and direct surveys to researchers are useful techniques, but are time-consuming and neither normalization nor benchmarking are possible.

Coverage, data collection strategy and sources

Data collection in AQUAMETH covered all or most PhD-awarding institutions in six countries (Italy, Norway, Portugal, Spain, Switzerland and UK), for a total number of 271 institutions; an extension to The Netherlands, France and Hungary is under way. By contrast, CHINC adopted a sampling strategy including only a limited number of HEI per country, but with a larger number of countries (including The Netherlands, Czech Republic, France, Denmark and Hungary, but excluding Portugal) and including also some non-PhD-awarding institutions for a total of 108 institutions (Slipensæter *et al*, 2005).

The data collection was based on national correspondents, who know the national systems and the sources of data; this strategy has proved to be valuable also in other recent indicators projects, as in the comparative analysis of public project funding

(Lepori *et al*, 2007). They faced an extreme variety of situations concerning the availability of data and their quality. While the situation differs slightly according to the variables considered, in general three types of situations were encountered (see Slipensæter *et al*, 2005):

- Countries where data on individual HEIs are centrally collected by national statistical services. These include Norway, Switzerland and UK.
- Countries where there are some centralized information, but not from statistical services. This is the case of Italy, where most of the data come from the publications of the Italian Conference of Rectors (CRUI) or the National Committee for the Evaluation of the University System (CNVSU), as well as Spain. Portugal used non-public information from the Ministry of Education.
- Countries where the information had to be collected directly from individual universities. These include Germany and Hungary. These are the most problematic cases since harmonization of the data even at national level was quite difficult; moreover, the data available and their quality differ significantly from university to university.

The analysis showed some problems of data quality and uniformity across years. This includes breaks in time series for aggregates that were expected to be quite stable — such as the total expenditures of a university — such as incomplete time series, and inconsistencies between data from different sources.

We notice that quality and coherency of data vary according to their sources. Thus, where statistical services are at work, they usually take care of some harmonization and checking of coherency. Problems are more severe where data had to be collected by non-statistical sources, such as annual reports or rector conference reports. As expected, using non-statistical information comes at the price of a lower quality of data. Methodologies to treat this kind of information should then be developed. We notice also that available data reflects to some extent the national governance structure of higher education: for instance, the well-developed statistics in Switzerland has been created for purposes of budgetary allocation; the same holds to a large extent for the UK

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and Norway. On the other hand, the limited budgetary autonomy of French HEIs impacts on availability of data (see below). We should then be aware that in most cases these data have been produced to manage funds and decision-making and thus they are to a large extent entrenched in institutional structures and power relationships (Godin, 2005).

Time coverage was for most institutions from 1994/1995 to 2003 with some missing years for quite a number of HEIs. Both our experience and the findings of the European Network of Indicator Producers (ENIP; Esterle and Theves, 2005) confirm that in many countries major breaks of series in S&T data occurred at the beginning of the 1990s. A longer time coverage would then require an expensive work of data gathering, analysis and correction (Table 2).

Data availability and related issues

In the data collection and analysis, a number of issues arose concerning availability of data, as well as their quality and comparability emerged. Further, we discuss how from these data it is possible to build indicators to answer some research questions.

Expenditures and revenues

For most HEIs it has been possible to reconstruct an aggregate value of *total expenditures*. The main exception is France where a large part of the permanent staff is directly paid by the central government, who publishes only national aggregates. In Hungary also producing time series was impossible for most institutions due to mergers and restructuring in recent years.

However, there are a number of issues. First, the perimeter of what is considered as university expenditures might differ between countries, for example, for annex services, social security payments of personnel and the separation between higher education and healthcare expenditures in university hospitals (OECD 2000, 2001). Second, capital expenditures are problematic to assess since in some countries these are still included in state accounts and not given separately for each institution. Even were data are available, accounting conventions — for example, the distinction between capital investment and current expenditure — are largely different across countries, and sometimes also across universities. Also, in some countries some large physical facilities (eg buildings) may not be the property of the university, but of other public or private institutions.

Table 2. National sources of data by category

Country	Main data source	Other sources
<i>Czech Republic</i>	Institute for information on education (UIV)	Publications: Thomson Scientific/ISI and national database for "Other publications" Patents: Industrial propriety office of the Czech Republic
<i>Denmark</i>	Directly from the institutions (no central data available)	Grants and contracts, and PhD degrees: the Danish Centre for Studies in Research and Research Policy Education production: Danish Ministry of Education
<i>France</i>	Ministry of Research and Higher Education	
<i>Germany</i>	Directly from the institutions (no central data available)	
<i>Hungary</i>	Directly from the institutions (no central data available)	
<i>Italy</i>	Conference of Rectors (CRUI)	Publications, ministry of education sources and CNVSU (National Committee for the Evaluation of the University System)
<i>The Netherlands</i>	Several sources (ministry, statistical office, research institutions)	Thomson Scientific/ISI publications: CWTS Leiden Other publications: Directly from the institutions Spin-offs: Study for the Ministry of Economic Affairs
<i>Norway</i>	National database for statistics on higher education	Number of PhD degrees: Register of PhD degrees, NIFU STEP Publications: Thomson Scientific/ISI analysed by NIFU STEP Patents: National patent office and NIFU STEP
<i>Portugal</i>	Directorate on Higher Education and Observatory on Science and HE, Ministry of Science and HE	
<i>Spain</i>	Vice-Chancellors Conference of the Spanish Universities (CRUE)	Personnel: National Institute of Statistics Education production: Council of University Publications: Thomson Scientific/ISI Web of Science Licensing revenues, spin-offs and patents: technology transfer offices
<i>Switzerland</i>	Swiss Higher education University System of the Swiss Federal Statistical Office	Thomson Scientific/ISI publications : Data are from the Centre d'Etudes sur la Science et la Technology (CEST)
<i>United Kingdom</i>	Higher Education Statistical Agency (HESA)	Publications: Research Assessment Exercise

Source: CHINC project report (Slipersæter, 2005a) with additional information on Portuguese sources

Also, data on physical capital stock are almost impossible to find. Limited data on classrooms (number of seats), linguistic and computer laboratories are available in some countries (eg Italy). No data on experimental equipment and laboratories are available. In some countries (eg Switzerland), there are data on floor space but cross-country comparison would require a detailed assessment of how these are calculated.

For these reasons we decided to exclude capital expenditures from input data in comparative analysis. This amounts to assuming that the use of capital is homogeneous across universities and countries, which is clearly an oversimplification. In the future, a dedicated study on technical coefficients should be done, going down to data on physical facilities. However, really solving these issues would require some standardization of accounting and reporting procedures of HEI at European level.

A major limitation of expenditures data is lack of disaggregation: in most cases expenditures can be divided only between personnel and functioning expenditures. Only in Switzerland and Norway it is possible to divide expenditures by scientific field.

In most public universities, *total revenues* should correspond roughly to total expenditures since these institutions have limited possibility for transferring funds from one year to the other. This generates a simple check for data coherency. Where data come from statistical offices, coherency is usually guaranteed, while in the other countries there are still some differences (especially for the Czech Republic and Hungary).

Quality and availability of data differ strongly according to the subcategories of the revenues. All countries, except France, produced an aggregate value for general funds from the state, even if there might be some borderline cases with government contracts (as a detailed analysis of the Swiss data suggests). With the exception of the Czech Republic, data are also reasonable concerning tuition fees, even if there is a need to check carefully to what extent fees from continuing education are included or not. In Spain, it is impossible to exclude grants and contracts from general government appropriations and thus data are not fully comparable.

The situation is more difficult for contract funding. Most countries produced totals for the “grants and contracts” category for most institutions, but a complete breakdown in subcategories was possible only in Germany, Norway, Switzerland and the UK. Data on private contracts were thus available only in these four countries and, even in these cases, quality is problematic since many private contracts are managed directly by professors and laboratories and accounting conventions may also differ. In the United Kingdom, for example, data include not only industry contracts but also private donations that in other countries are included in other funding. In Switzerland, a break in series occurred in 1999 when subsidies from private foundations were transferred

to the general budget. For public sector contracts we suggest in the future a cross-check with the national aggregates which have been produced in the European Network of Indicator Producers funding activity (see Lepori *et al.*, 2005).

Finally, we notice that comparisons cross-country and across time have to comply with the lack of deflators and purchasing power parities specific to the higher education sector, since the cost structure differs significantly from the baskets used for the general gross domestic product deflators and purchasing power parities (PPPs). Despite some methodological work at the OECD from the 1970s (see discussion in *Frascati Manual: OECD*, 2002: 217ff.) these converters are not routinely produced by statistical offices nor used for international comparisons.

Personnel

Personnel data are easier to get than financial data (Jacobsson and Rickne, 2004) and actually all universities are able to provide some estimate of the total number of personnel. However, in some countries (such as Italy and Portugal) only headcounts are available, which can be problematic since not all staff is full-time (especially for contract researchers). We notice that the distinction between permanent and temporary staff is largely bound to national legislation or the legal structure of the university rather than to the real position of the personnel, and thus it is highly problematic to get valid data without detailed examination of individual cases.

A complex issue concerns personnel categories, which are closely dependent on the organization of careers at national level. The number of professors is usually available, either as an aggregate of all professors or disaggregated by the various titles (full, associate, etc). Positions such as ‘researcher’ or ‘research-only staff’, on the other hand, exist only in countries where a specific career for non-teaching staff exists (eg Italy, Spain, The Netherlands, Norway), while in others, personnel with the same function might be labeled differently (eg a general post-doc category including both research-only and teaching-only staff). Some countries also have categories on teaching-only personnel. In addition, in countries with very large numbers of PhDs in natural

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and technical sciences, some of them in reality perform functions similar to support and technical staff. All these variations make the use of indicators based on the composition of staff categories difficult.

However, perhaps the most intriguing issue comes when considering PhD students. Are they inputs of the research process, or just outputs of the educational process? Clearly both, but in unknown proportions. Moreover, the data show considerable differences between countries concerning the number of PhD degrees, reflecting the various roles the PhD plays in the countries considered and the organization of PhD studies (Jongbloed *et al.*, 2005). The requirements for entry into the national labor market is one of the determining factors, while the status ascribed to the PhD students is another. In a country such as Norway, most PhD students are on contract with mostly the same rights and obligations as other personnel. In other countries, PhD students are given the same rights as undergraduates. These and other variations in the role of PhD students are reflected in the number they make out of the total student population.

To solve the issue of variations of roles of PhDs, we propose two solutions:

1. *Ex-post allocation.* In some countries (eg Switzerland, Norway), PhD students receive a separate contract for research and they are included in the academic personnel and the appropriations for their research contracts are included in the funding data. In other countries, where this is not true, we are left with the problem of estimating the contribution of PhD students to research. We propose to allocate 50% of the PhD count to the number of academic staff and hence 50% of the estimated annual cost of PhD students to personnel expenditures.
2. *External variable.* Another useful strategy is to let the number of PhD students vary externally to the efficiency model applied, exploiting the recent developments of robust nonparametric techniques. The ratio between unconditional research efficiency and research efficiency conditioned on the number of PhD students gives a precise measurement of their impact.

Education production

In general, student enrollments and degrees are among the most reliable data from HEIs, and numbers of degrees are normally considered the more reliable (Salerno, 2003). However, there are also a number of issues to be addressed. Large variability still exists across countries in the precise meaning of what a student is. In some countries, such as the United Kingdom, there are many part-time students (around 22–25% of the total), that require less resources from the university. In other countries, such as Germany, it was reported that many students do not attend the university but still apply in order to

receive social welfare benefits. In Italy this was typical of the situation before the adoption of the 3+2 system. This is a concern for time series since changes in enrolment rules might easily modify the number of students over time.

For all countries, we followed the strategy of specifying two separate variables: enrollments and degrees. Systematic differences in efficiency score when the two variables are used will call the attention to possible inefficiencies in the use of university services by students.

For *undergraduate students*, we assumed the standard ISCED 5A-level definition, that is, students that attend a curriculum with duration of at least three years are defined as undergraduates. Differences in the length of curricula are considered not important, particularly after the Bologna process, but we should consider that in most non-PhD-awarding institutions the normal duration of a curriculum is three years.

Similar problems apply to *Master degree students*. On the one hand, the duration of a Master program may vary (one to two years). On the other, in some countries (eg Portugal) students may apply to a Master program and stay enrolled for several years before graduation, and even leave the program without a degree.

The introduction of the Bologna models leads to some complexity in what to consider being the 'first' university degree. In many continental Europe countries, the first degree is normally considered the Bologna master degree (after a five-year curriculum), while the bachelor degree would be considered as an intermediate step. However, this is not true for countries such as the UK and for universities of applied sciences. Since these are differences linked to national systems, the national correspondents were left some freedom to decide on which has to be considered the 'first' university degree. This could of course affect comparisons.

Research and innovation production

The measurement of research and innovation output is the most problematic domain in the AQUAMETH and CHINC databases. The main routinely used indicator is the Thomson Scientific/ISI publication. The limitations of Thomson Scientific/ISI data are well known, particularly in human and social sciences (Hicks, 2004; Nederhof, 2006). The importance of this indicator is proportional to the importance of scientific and technical schools and departments in the university. Also, the problem with limitations of Thomson Scientific/ISI data is larger for non-English speaking countries. In a comparison between UK and other European countries, the implicit advantage of publishing in native language should be considered.

Moreover, it has to be pointed out that the innovation activities carried out by the HEIs, which can be measured to a certain extent by patents and licenses,

represent only a part of the broader concept of the so called “third mission” activity of HEI consisting mainly in knowledge valorization activities. Bonaccorsi *et al* (2006, 2007), for instance, use the percentage of funds raised from the market, and hence not coming from the government, as an indicator to proxy the intensity of knowledge valorization activities other than innovation indicators.

In the project, Thomson Scientific/ISI data coming from secondary national sources (Ministries, Evaluation agencies, Conference of Rectors) were used, since we had no direct access to Thomson Scientific/ISI data. Also access to these data proved to be very problematic or expensive (as in the case of the UK). In other countries where data have been analyzed by public services it was impossible to get the original data to perform more detailed analysis (as in Switzerland). Clearly, urgent action is needed to ensure public access to Thomson Scientific/ISI data to the scientific community with reasonable conditions. As there are numerous problems with Thomson Scientific/ISI data (such as the problem of attributing correct institutional affiliation to authors), data validated and analyzed by others have to be handled with extreme care and should probably be validated in a more accurate way than was possible in our context. However, they represent the best available estimate of the portion of research results published in international journals.

While number of PhD degrees and Thomson Scientific/ISI publications can be used to some extent to measure international academic production, the situation is more complex for other outputs. For innovation outputs some indicators have been developed in the literature, such as number of patents and spin-off companies (see Schmoch, 2004, for an overview), but the only standardized data at the level of individual HEIs come from an OECD survey, whose quality, according to information from some universities, is questionable since information was collected from central technology transfer offices and not cross-checked with other sources (OECD, 2003). Data on patents and spin-off companies from international databases are also problematic because they often relate to academic personnel as persons and not to their institutions. Identifying a patents link to a university can thus be very difficult. Service activities towards private companies and the public administration are even harder to measure; a useful proxy could be the number of contracts with these users, but a suitable methodology for collecting these data has yet to be developed. We notice that the issue is particularly severe for non-PhD-awarding institutions, which, at least in Switzerland and in the Nordic countries, are strongly oriented towards service and technology transfer to the regional economy (Kyvik and Skovdin 2004). Because of these problems, we refrained from constructing indicators including innovation output.

Construction of indicators

Except in some specific cases, data are not directly used as such, but rather to build indicators to answer specific research questions. Even if indicators are normally built from some mathematical combination of the underlying data, they differ for their meaning. Data are measures of physical quantities, for example, counting the number of students enrolled at a university or the number of publications with an author affiliated to a university. By contrast, indicators are constructs that are supposed to measure some abstract property, based in general on a theoretical model, but also normally on a body of empirical research (Van Raan, 2004).

Good indicators should share two main features: first, they should be *well-founded in theoretical terms*, meaning that there should be some underlying explanation for the assumption that they correctly represent a given feature of reality. For instance, scientific publications are considered as a measure of *academic productivity* both from sociological considerations on the role of publications in science and from empirical research in bibliometry, while PhD degrees per undergraduate students are usually taken as a measure for the *research intensity* of a university (McCormick, 2004). In other cases, the foundation has to be sought on some practical evidence; it is, for example, known that most of the grants and contracts attributed to a university are used for research purposes and thus their share in total revenues is used as a measure of *research intensity* (Bonaccorsi and Daraio, 2007b). If we also believe that grants are attributed based on the quality of research; this indicator could be used also as a measure for *research quality*. We notice that indicators require normalization to have a meaning: for example, a level of one PhD degree per 100 undergraduate students is considered in the US Carnegie classification to be the threshold for research-intensive universities (McCormick, 2004). Another indicator concerns the measure of the *quality of education* (see eg Salerno, 2003). Number of enrolled students over academic personnel can be used as proxies. Of course, normalization can and should be quite different for each specific context.

Second, good indicators should be *robust against limitations in the underlying data*. Thus, comparisons between institutions of absolute cost levels per student should be avoided since these are affected by differences in accounting systems between countries, the use of PPP for international comparisons and, finally, strongly depend on the subject mix of the institution. By contrast, we expect the evolution of the cost level between two years for a single institution to be more robust since some of these problems should affect in a similar way both the numerator and the denominator. Examples of indicators we used in AQUAMETH and CHINC are the share of different funding sources for each institutions and its variation over time (Lepori *et al*, 2007a) or the

number of Thomson Scientific/ISI publications and PhD degrees per academic staff as measures of research productivity and intensity (Bonaccorsi and Daraio, 2007b). This list and the analysis developed with these indicators have to be considered as a contribution towards the definition of a basic set of indicators to characterize the structure and the dynamics of European HEIs.

Comparability issues and interpretation strategies

Data problems are only a part of the more general comparability issues, coming from differences among national systems, characteristics of the individual HEIs and so on. Some comparability problems are embedded in data availability; according to the structure of national systems, we get different data. Other problems are located at the level of individual university and deal with its 'ontology' as an object of analysis. In other cases they rely on the interpretation of data; the same number may tell a different story according to the national context or the type of HEI. These cases call our attention to the need to 'contextualize' data and available indicators in their institutional and national context, on the one hand; and to take into account these specificities in the statistic and econometric analysis on the other hand. There is no general answer to these issues. We have to combine careful and detailed knowledge with the appropriate level of abstraction in identifying useful categories and statistical and econometric solutions.

New analytical approaches can also help solve some of the problems. Bonaccorsi *et al* (2006) show that using recently introduced robust nonparametric methods (Cazals *et al*, 2002; Daraio and Simar, 2005) with their related graphical tools (for a comprehensive presentation see Daraio and Simar, 2007), some national specificities can be caught, without imposing at the beginning a strong formalization of the relationships between the inputs-outputs-external factors as required by traditional (parametric) econometric techniques. They propose these new nonparametric and robust techniques as exploratory tools to detect a first approximation of important phenomena in research and HE policy such as trade offs in teaching vs. research; the role of PhD in the research activity, and so on.

For analytical purposes, it is useful to distinguish between two main sources of comparability problems, namely, differences in the *organization and governance structure of national higher education systems* and *heterogeneity of the individual HEI*.

Institutional context

An important source of heterogeneity between universities comes from the ways institutional systems are conceived across European countries. There is a

large body of literature on the system-level governance of higher education systems and on its changes during the last two to three decades (Clark, 1983; Neave and Van Vught, 1994; Amaral *et al*, 2002).

We notice that, at least in federal countries, the institutional context can be heterogeneous even at national level as the Swiss case demonstrates (Lepori, 2007). With the increasing role of the regions in the European Research Area, the issue of the impact of regional differences — concerning levels of economic development, industrial structure, and support measures — is also increasingly important (Larédo, 2003).

Dual systems Many European countries have a system in which the higher education system includes universities but also non-PhD-awarding institutions, such as Fachhochschulen in Germany, Hogescholen in The Netherlands and Universities of Applied Sciences in Switzerland (Huisman and Kaiser, 2001; Kyvik, 2004). In most cases, these HEIs differ clearly from universities concerning their organization, education and research output. In other countries (eg Norway), we see a transition of such institutions as they are obtaining the right to award PhDs within a limited set of scientific fields. The appropriate strategy here is to carry out all analyses separately and to specify models differently. However, the interactions between the two sectors should be considered, especially concerning education, since the existence of these 'second type' institutions tends to lower the number of undergraduate students in universities. Moreover, in countries such as Switzerland, Norway and Finland, these institutions are relevant players in 'third mission' activities towards the private economy.

Private vs. public universities In the European context, universities are predominantly public institutions. Nevertheless a number of private institutions exist, usually recognized and sometimes partially funded by the government. The classical solution of a dummy variable is appropriate here. It allows estimating the variability in efficiency across the two categories, as well as the variability internal to the categories. Another possibility may be to carry out two separate analyses, one for private and the other for public universities. We notice also that data are not fully comparable between the two categories owing to different legal status (eg commercial accounting in private universities) and different requirements to collect data.

Public research organizations In some countries, a large part of scientific research is carried out not only by universities, but also by large public research organizations (PROs), such as CNRS in France, Max Planck in Germany, CNR in Italy and CSIC in Spain. Thus, any analysis of HEIs should take carefully into account the relative role of universities and PROs in the production of research

output, as well as the interaction between these actors in terms of joint production of research output.

This issue is particularly relevant for countries, such as France and to some extent Portugal, where mixed units are widespread and, hence, it is difficult to identify clearly the perimeter of the HEIs. Thus in France joint laboratories between CNRS and universities include people funded by both institutions and research contracts might be managed through both sides; also, institutional affiliation of publication and patents is handled case by case and thus it is quite difficult to separate inputs and outputs between university and CNRS. There is no easy solution to this issue since it reflects an underlying organization of the research system. A track which could be investigated is to consider CNRS as a funding agency and to include all joint laboratories in the university perimeter; however, this would require in data collection from both sources.

Age and structure of universities In other cases, there might be large heterogeneity according to the age of universities, if in the history of higher education a discontinuity has been produced (Bonaccorsi and Daraio, 2007b). The age of the university is of course not what matters *per se*, but the age is likely to reflect specific characteristics of the institution. Many older universities are likely to be broadly research-oriented universities, while the younger ones might be more specialized. This again might affect funding possibilities and research intensity. An interesting case is the United Kingdom, where universities include also the so-called 'new universities', being the older polytechnics, which were where transformed into universities in 1992 (with the right of granting PhDs). A methodological solution for efficiency analysis is to include the age of the university as a descriptor and to consider it in estimations. Another solution, once the qualitative analysis has shown large enough differences, is to introduce a break in the sample and to estimate efficiency separately for the age categories.

Funding pattern One might also consider that a large amount of heterogeneity is introduced by differences in funding, since national funding systems are quite different across Europe concerning the level of funds and their composition. We have dealt with this source of heterogeneity by computing the share of funding coming from different sources.

A methodological solution for efficiency analysis is to include the age of the university as a descriptor and to consider it in estimations

These composition rates can also be used as external variables in robust nonparametric techniques, in order to understand whether patterns of funding really matter. For example, Bonaccorsi *et al* (2006) estimate the relative impact on efficiency of Italian universities of the share of funding coming from private sources. Moreover, we analyzed systematically the relative importance of national and institutional patterns across the sample, showing that the share of tuition fees is essentially nationally determined (with the exception of the UK); whereas the share of grants and contracts shows much greater variations between individual institutions (Lepori *et al*, 2007a).

Heterogeneity of individual HEIs

Another fundamental issue is the level of heterogeneity at the institutional level, as the result of differences in the institutional systems, as well as the outcome of historical developments and strategic decisions. Disentangling these effects is rather difficult.

Disciplinary mix Universities may have very different profiles in terms of faculties and schools they are composed of, and hence of educational activity and research output. From the teaching point of view, strong variations in cost per student are likely to occur, due to differences in capital intensity (laboratories), length of curricula, type of training (theoretical, applied, practical experience) and so on. In the Swiss case, we could show that resources per undergraduate student differ by a factor of about 10 between human and social sciences and medicine (Filippini and Lepori, 2007). Also, from the research point of view, disciplines exhibit diverse publication patterns, in terms of average number of co-authors per paper, average number of *per capita* papers per year, and the like. Ignoring these differences may be misleading.

Tackling the disciplinary mix issues is complicated by the lack of data disaggregated by discipline for most inputs and outputs. In AQUAMETH it was possible to get disaggregated data concerning student numbers at least for the main domains of the OECD fields of sciences and technology classification (OECD, 2002: 67). Concerning staff, disaggregation would be in principle possible for some countries, but national schemes do not always comply with the OECD classification, while only in Switzerland can expenditure be divided by field of sciences. Similar problems exist for scientific publications.

Several possible strategies have been developed to tackle these problems:

1. *Dummy variable* We have constructed a dummy valued "0" if the university does not have medical schools; "1" if the university has a medical school (but not a hospital), and "2" if the university maintains both a medical school and a hospital.

This is relevant since faculties of medicine can account for half of the total expenditures of a university and the separation of costs between higher education and healthcare is highly problematic (OECD, 2001).

2. *Categorization* We built a concentration index by computing the distribution of students in four broad disciplinary areas (human and social sciences, technical sciences, natural sciences, medicine). Following a standard notation in economics, C_1 is the concentration index for the largest discipline, C_2 for the first two, etc. We define as a Specialist a university with $C_1 \geq 0.70$ or $C_2 \geq 0.90$ and as a Generalist otherwise. Of course, other specifications can be explored. Once a categorization is accepted, analyses can be carried out separately. As an example, Bonaccorsi *et al* (2006) have used this categorization to compare the productivity of research across European country analyzing only "Generalist" universities.
3. *Test of hypotheses* Once the external variable has demonstrated that efficiency is strongly influenced by heterogeneity, it would be possible to split the sample according to the identified variable and perform analysis separately.
4. *Multi-layer models* Still another possibility is to apply nested models, that is, start with small samples and include them into larger ones (Raudenbush and Bryk, 2002).
5. *Data envelopment analysis* with the use of restricting virtual weights (Sarrico and Dyson, 2004).
6. *External variables* In some cases it is not well understood whether heterogeneity in the disciplinary mix really matters for the analysis. A suitable technique is made possible by conditional robust nonparametric methods (Daraio and Simar, 2005). These allow the estimation of the impact of external variables on efficiency scores which may change in a non-linear way on the relevant distribution, offering the opportunity of catching local effects.

Towards 'meso' data on the European higher education system

We think that our approach led to a real progress in the analysis of HEIs: despite all the limitations discussed above, the collected data proved to be usable not only for national analysis, but also for comparative analysis across countries concerning efficiency (Bonaccorsi *et al*, 2006) and funding models (Lepori *et al*, 2007a). In our view, this result is due to a combination of three main elements:

- The definition of a *minimum core of data* that realistically can be collected from existing sources without posing unsolvable methodological problems. This strategy led, for instance, to the exclusion of data on investments and capital costs.
- The project organization based on *national correspondents* in charge of retrieving and correcting

the data based on their knowledge of data sources and of the national higher education system. This allowed the use of unconventional sources for countries without a well-developed higher education statistics such as Italy and Spain. Correspondents' expert knowledge was also essential for data handling and interpretation of results.

- A *careful usage strategy* of the collected data with awareness of data limitations and that tries to overcome them with suitable techniques.

This positive result should not overshadow the limitations of the collected data and the need for improvements. Some of them, as already discussed, simply reflect the heterogeneity between the national higher education systems of Europe, which is a major difference between Europe and the USA, as well as between individual HEIs. These issues call for a further interpretative effort, linking systematically quantitative data with contextual information on individual countries and institutions.

However, some limitations bring back more directly issues of data quality and availability. First, despite our efforts, we are aware that to ensure the quality of data, more systematic validation procedures should be introduced. Second, we still lack in many cases a clear understanding of the level of comparability of the data. For instance, on some of the issues raised above — such as differences in accounting systems or in definitions of students and degrees — we are not sure if they simply produce noise in the observed patterns or if they alter them fundamentally. Finally, there are some domains where little progress can be done without advances in the methodology and the practice of data collection; this is the case for capital costs and for most output indicators, including scientific publications and third-mission indicators.

Summing up, we claim that from a long-term perspective, the maintenance of a dataset like that developed in AQUAMETH and CHINC goes beyond the possibility of a research project, especially if the intention is to enlarge it to most of the European HEIs (thus going up to about 3,000 institutions). At the same time, the approach chosen here is rather far away from the one adopted by statistical agencies, since it is more centered on the production of indicators from existing data than on the collection of coherent data sets in statistical terms. It exploits largely the work of Eurostat, OECD and national statistical offices, but it adds a further layer of complexity in three directions. First, it takes explicitly into account the heterogeneity of national systems and of individual institutions rather than trying to harmonize statistics. Second, it focuses on individual HEIs rather than on national systems as the main reference level. Third, it covers a wider range of indicators concerning issues such as third-mission output of HEIs, and in the future also regional indicators, which are clearly needed for research in higher education and for policy analysis.

Finally, we will advocate the need of a European Science and Technology Indicators Platform (ESTIP) as proposed by the PRIME Network of Excellence (Barré, 2006), which would allow maintaining and developing these databases from a long-term perspective. In this respect, both the approach by another

PRIME project, the European Network of Indicator Producers (Esterle and Theves, 2005; Lepori *et al.*, 2007b), the AQUAMETH and the CHINC projects have brought a number of interesting results and indicators, and have as well convincingly been demonstrating the possibilities of a Europe-wide approach.

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Notes

1. AQUAMETH, Advanced Quantitative Methods for the Evaluation of the Performance of Public Sector Research, a project within the PRIME Network of Excellence coordinated by Andrea Bonaccorsi and Cinzia Daraio, University of Pisa, Italy.
2. CHINC, Changes in University Incomes: Their Impact on University-Based Research and Innovation, funded by the Institute of Prospective Technological Studies of the European Commission and coordinated by Stig Slipersæter, NIFU-STEP, Norway.

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