Measurement of Teaching and Research Outputs in Higher Education

Arumugam THILLAISUNDARAM*
Universiti Tunku Abdul Rahman

Abstract: This paper focuses on the issues involved in the measurement of university outputs, especially teaching and research outputs. It gives descriptions of university outputs by various higher education economists and goes on to describe the conceptual and practical problems of measurement of research and teaching outputs in higher education. Besides describing the measurement methods currently in use, their general features, advantages and weaknesses, the methods developed by the author to measure teaching output and research activity are also discussed. The UK university system as it existed prior to 1993 provided the background for the author to develop the measurement methods for university outputs. The author concludes that while measurement methods for teaching are not contentious, those used for research output are still not sufficiently comprehensive and therefore likely to be controversial. Researchers need to give more thought to this issue in order to come up with a generally acceptable method.

1. Introduction

Universities produce three general categories of output. Economists have described these outputs in various ways. Bear (1974) describes them as (i) increments in human capital which benefit both the individual graduate and society at large; (ii) entertainment services (enjoyment of the curriculum and facets of college life) which are consumed by the students while in the university; and (iii) increments in the stock of knowledge.

Verry and Davies (1976), however, viewed university outputs as generally being made of (i) instructional or teaching outputs (transmission of knowledge); (ii) research outputs (knowledge extension); and (iii) general social services (socialisation of students, storage of existing knowledge, consultancy services, etc.).

Cave *et al*. (1988) considered universities as transforming inputs (students' time, academics' time, consumables and equipment and buildings) into teaching and research outputs. Teaching output is described as the value added to students receiving tuition from a university or other higher education institution irrespective of whether they complete their course of study or not. Research output refers to all additions to knowledge produced by a university or higher education institution in the form of publications, patents, development work, etc. Some outputs of higher education, they say, are used as consumption benefits by students and other participants of higher education.

Bowen (1980), however, deals with university outputs in terms of education, organised research and public services. University outputs are thus basically in the general form of teaching, research and general social or public services. Teaching outputs are usually expressed

*Faculty of Accountancy and Management, Universiti Tunku Abdul Rahman, Lot 8, Jalan 13/4, 46200 Petaling Jaya, Selangor, Malaysia
Email: *thillai@mail.utar.edu.my*

in the form of diplomates and graduates, and that of research in the form of publications etc., while public service may take many different but unexpressed forms.

2. Problems of Measurement

Researchers of higher education are aware of the conceptual problems of measuring the outputs of universities. There is a fundamental and pervasive problem of measuring higher education outputs on which depends the success of applied economic analysis of costs and efficiency (Verry and Davies 1976). Part of the difficulty of this is attributed to the fact that outputs are not sold on the market and thus aggregation of different types of outputs through the use of market prices, a standard procedure of economists in multi-product manufacturing situations, is not possible. Verry and Davies (1976) indicate that there are theoretical problems, for non-profit organisations with multiple outputs, in specifying, estimating and interpreting multi-product cost and production functions.

2.1 Conceptual Problems in Measurement of University Outputs

University inputs and outputs are not homogeneous and can be aggregated (or disaggregated) by disciplines, institutions, courses, states etc. These add to the difficulties of measurement and often a decision has to be made as to the level of aggregation to be employed in economic studies of universities (Archibald 1974). A more recent view of the fundamental difficulties of comparison of university outputs especially research output is that of O'Brien who says, "Academic knowledge is not a homogeneous form of output that can be easily compared across or even within disciplines. There are fundamental differences between the nature of knowledge and the way it is produced by departments of science on one side and departments of social studies and humanities on the other. Professional schools also seem to form a separable industry or category." (O'Brien 1994: 16).

3. Evaluation Methods for Higher Education

Cave *et al*. (1988) indicate that, historically, a number of techniques have been used to evaluate the efficiency of higher education and that these usually involve the establishment of the relationship between inputs and outputs. The differences among the techniques are in the stage at which the inputs and outputs are measured, the units in which the inputs and outputs are measured, and the level of aggregation. Cave *et al*. (1988) describe cost-benefit analysis and cost-effectiveness analysis as the traditional techniques of evaluation and data envelopment analysis as an alternative to cost-benefit analysis.

Cost-benefit analysis has been used to ascertain the rate of return to investment in higher education for the individual student and for the economy as a whole (Ashworth 1997). Cost here refers to the aggregated teaching-related costs, and benefits are the estimated discounted value of increased earnings resulting from higher education. Research has not been assessed this way because of the difficulties in establishing the economic benefits of research.

Cost-effectiveness analysis is another technique which has been used in higher education. Cave *et al.* (1991) describe this technique as being limited in scope. This technique utilises the inputs in money terms and the outputs in physical units which in higher education would be, for example, the number of graduates or the number of research publications. The major problem in this approach is one of ensuring that the physical unit reasonably reflects the characteristics of the output. This assumption is normally acceptable when the outputs are homogeneous but there are quite high variations in the outputs of higher education especially with regard to quality. In cost-effectiveness analysis, no attempt is made to capture the differences in the outputs. The measurement of output is thus done simply, for example, by just counting the number of students who have graduated.

Data envelopment analysis is a recent alternative way of assessing inputs and outputs adopted by higher education institutions. This approach is used to choose the most efficient method of doing an activity and also of revealing the closeness of a department or an institution to the efficiency frontier. Studies have been made by various researchers on the efficiency of university departments using this method. The study by Beasley (1990) examined efficiency in chemistry and physics departments. Johnes (1992) applied this approach in assessing research performance of economics departments and reports on its usefulness as a performance indicator. Tomkins and Green (1988) used this approach to gauge efficiency of university accounting departments. Cave *et al.* (1997) indicated disappointment that this method has not achieved substantial impact as a tool in the assessment of performance in higher education. They, however, felt that it has a role to play in bringing about an understanding of the higher education process at a conceptual level.

4. Teaching Output

Archibald (1974) argues that there are many ways in which a university's teaching output can be considered. The teaching output, for instance, could be examined course by course for student attainment, partly as an output in itself and partly as an input into subsequent courses. These could be aggregated arbitrarily into a unit of teaching output labeled as 'a degree'. The attributes of the teaching output (degree) may be classified as follows:

1. Investment in a consumer durable
2. Investment in a source of future externalities
3. A current consumption activity
4. Investment in a producer good (human capital).

There is some weighted combination of these four elements in each degree programme. A university produces all four attributes; however, the weighting differs from programme to programme.

This difference in the weighting of the attributes among programmes adds to the measurement problems of a university's teaching output. Archibald indicates that economists have been concerned mainly with the quantification of attribute (4).

There is no obvious natural or physical unit in which increments in human capital (teaching) produced by universities can be measured (Bear 1974). Verry and Davies (1976) describe the teaching activities of universities as contributing to the increase in human capital and also to the current consumption benefits of students. But they too similarly indicate that though it would be ideal to measure these different types of teaching outputs, it is not possible. This is because there are no clearly defined physical units of human capital or current consumption output. There are also no appropriate unit market prices by which these outputs could be valued.

That there is no single measure of teaching output is a general conclusion of Archibald (1974). The quantity of human capital appears to be impossible to measure directly. The alternative is the measurement of some indirect reflection of it. Human capital is an unobservable attribute and its measurement depends on some other element that is (i) measurable and (ii) attributable to human capital (Bear 1974).

4.1 The Value Added Approach

Additions to human capital which a university's teaching activities produce can ideally be measured (in the absence of physical units of human capital) by the application of the value added concept. The value added concept involves ascertaining the difference in a person (in terms of knowledge, skills, general social ability, etc.) as a result of undergoing higher education. Basically it is aimed at identifying the contributions of the inputs of the university to the change achieved in the person.

Cave *et al*. (1988) describe the features and difficulties of the value added measure which are summarised briefly here. According to them an assessment of value added may be made simply by the comparison of entry qualifications of university graduates with their exit qualifications from the university. This approach, however, may be considered insufficient and the measure could therefore be expanded by giving a substantially broader meaning to value added. Value added could be made to include the contribution aspect of higher education to society. Higher education is of benefit to the individual in three ways: (i) consumption benefits of going through the higher education experience; (ii) potential higher earnings; and (iii) personal development. Benefits also flow to society by having a highly educated individual within it who may produce positive external effects on it.

It is necessary to measure value added in order to get information on input-output relationships so as to ascertain whether the higher education process is efficient. Value added may be expected to be higher in efficient institutions than in less efficient ones given similar resource levels. A value added measure could also be used to ascertain returns to scale in teaching much more than allowed by current methods of measuring teaching outputs through the use of proxies.

It would be tedious to measure value added, individual by individual. The methods used in practice involve comparison of input quality with output quality. Under these methods the academic achievements of students at time of entry are usually compared with their achievements at time of leaving the institution. Any difference is attributed to the value added by the institution's educational process. There are, however, problems with this approach, say Cave *et al.* (1988). For instance, different qualifications have different social values attached to them. The financial compensation by the market varies from one type of degree to another type and the social benefits of each qualification are not identical. There are also operational difficulties in measuring value added of different institutions. To enable comparison between institutions, tests are made on a standard format. The motivation to excel in these standardised tests may lead to adaptation of the teaching practices in order to obtain high scores. Thus the test scores become a definition of quality rather than a measure of quality. When this happens value added may not serve as a tool for making selective decisions between institutions. In addition, concurrent assessment of value added of all institutions can involve substantial time and money.

5. Research Output and Quality

5.1 Research Output – Measurement Issues

Just as in teaching, there are neither conventional units to measure research nor conventional market or non-market prices through which it can be valued. Bear (1974) suggests an approach for dealing with the measurement problem. His ideas are summarised in the ensuing paragraphs. Research can be viewed from two aspects. The first is the discovery or creation of new knowledge and the second is the dissemination of that new knowledge to society. Provided knowledge is measurable, then measurement can be made at either discovery or dissemination or both. The two measures, however, are unlikely to agree because not all discovered knowledge is necessarily disseminated. Measurement of research output at the dissemination stage would be socially and economically preferred as the major social and economic benefits of knowledge are obtained when it is widely distributed. This, however, requires a measure to be devised that can record the quantities of new knowledge that is disseminated. The quantity of disseminated new knowledge could be obtained by multiplying units of knowledge by the number of people acquiring it. This approach is not possible, however, as there is no natural unit of knowledge.

The published page could be used as an approximate (but highly imperfect) unit by which the quantity of disseminated knowledge could be measured. This method may require that new knowledge be published as a way to meet the condition that knowledge is disseminated. Publication does not, however, mean that dissemination of knowledge has taken place. Publication also does not mean that there has been readership and in the scientific community sometimes "unpublished" early drafts of papers perhaps given at conferences or circulated as working papers may be the means through which the advancement of knowledge is carried out, leaving its wider dissemination as the role of formally published papers. Knowledge may have to be disaggregated into various types in order to reduce the simplicity of this approach. The disaggregation could be done by discipline as well as by fields within discipline. Quality could also be used as a basis for further division.

The mere counting of published pages to determine the quantity of knowledge disseminated is, however, weakened by the fact that more pages do not necessarily mean more knowledge disseminated. A shorter research paper may be of higher quality, have a wider readership, and have a stronger eventual impact on society. Bear (1974) concludes that despite these weaknesses some counting procedure is necessary to make progress in the measurement of research.

Verry and Davies (1976) suggest that it is preferable to measure research in terms of physical quantity, quality and value but that because there are no units of knowledge and no means of valuing it, research has to be measured through surrogate measures. They describe input-based and publication-based measures as the usual surrogates for the research output in studies of higher education. They themselves used the annual hours spent by academic staff on personal research (an input-based measure) as a proxy measure of research output. They found input-based measures not suitable as they would not facilitate cost-benefit analysis and also because of the problem of allocating costs in a multiple-output situation. Publication-based measures were considered better as they are not subject to the limitations of the input-based measures. However, despite the limitations many researchers use input-based measures especially financial inputs. This is because information on financial inputs such as research income is easily available in published form and is not ambiguous. Research income or expenditures (an input) have been used as a proxy for research output, for example by Cohn *et al*. (1989) and Beasley (1990).

A measure or an index of research output independent of inputs would be desirable, say Verry and Davies (1976). The alternative they advocate is a method based on the quantity and possibly quality of academic publications. Under this method there are various possibilities, namely (i) number of published words; (ii) number of pages [as suggested for example by Bear (1974)]; (iii) number of articles or books; or (iv) the number of citations received by articles or books. Verry and Davies (1976) used the number of articles and books published by a university department's academic staff as proxy research output in addition to the research time measure. In this case they used differential (arbitrarily chosen) weights for books and articles to allow for quality. Number of research publications as a measure of research output has also been used by de Groot *et al*.(1991).

The weaknesses of the published page measure have been described earlier and also apply to other publication-based measures. Verry and Davies (1976), however, add that many unpublished works contribute to knowledge whereas some published materials do not necessarily add to knowledge. Review articles and text books, for example, contribute mainly to dissemination of existing knowledge. There can also be some double counting when books and articles are included as articles are often collected and expanded to form books without major contribution to knowledge. Quality is another problem in publication-based measures as there are wide variations in the quality of articles published and there is no appropriate set of relative prices for aggregating them. Various approaches have been suggested to overcome these difficulties but each has its particular weaknesses. Even the Research Assessment Exercises in the United Kingdom, whatever the procedures in place to ensure objectivity, are ultimately a matter of subjective judgement (Whittington 1993: 392).

5.2 Citation Analysis

Citation analysis can be considered as a surrogate measure of research quality but a linear relationship between research quality and the number of citations cannot be generally assumed as there are situations where high quality articles are not frequently cited but highly cited papers, however, may be considered as having greater impact (CVCP 1989). In citation analysis, quality may be taken as representing the impact an article has had on a subject and its improved understanding (Cave *et al.* 1997).

Citation analysis involves making a count of the number of times an article is cited over a defined period. This could be done at an individual or departmental level. Data on citations are collected by the Institute for Scientific Information (ISI) and published in the Science Citations Index (SCI). There are also other indexes such as the Social Sciences Citations Index, and the Arts and Humanities Citation Index. Citation analysis has several advantages and disadvantages in application. Its advantages according to CVCP (1989) are (i) it gives an alternative and additional measure to count of publications; (ii) when the citation analysis has been done long enough, it can give information on trends; (iii) some aspects of citation such as self-citation or own-group citation can be eliminated; and (iv) complementary indicators such as a proportion of publications not cited can be calculated. The disadvantages listed for it are (i) that it is labour intensive to some extent despite computerisation; (ii) there is a waiting period of at least three years after publication before assessment of the citations can be made;

(iii) departments which are small may not be able to produce enough citations to be useful in statistical analysis; (iv) some sources of publications may not be covered by the indexes mentioned above and thus their citation count may be underestimated; and (v) citation practice may be different between science and the humanities and may need a different interpretation.

Johnes (1992) mentions other problems associated with this form of tracking research output. He says that this measure is about impact and that impact does not necessarily equate with quality. For instance, he notes that an article may be cited frequently not because it is of high quality but because it is wrong. He also adds that it may not be a suitable measure when for example two or more authors are involved in writing an article as only the first named would be counted by the index concerned.

6. Surrogate Measures for University Outputs

Bowen (1980: 5) states "there is simply no known way, except through the broad general judgements of experts, to measure the output of an institution's organised research or public service programme." In respect to teaching there is, he says, a tenable measuring unit, i.e. full-time equivalent (FTE) student with appropriate adjustments. In the absence of discrete units in which to measure university outputs, proxy measures have to be substituted. Most often full time equivalent student numbers have been used as proxy output for teaching (Verry and Davies 1976; Tierney 1980; de Groot *et al.* 1991; Getz and Siegfried 1991). A few researchers (Carter 1965; Bowen 1980) have utilised student units (an extension of student numbers) as proxy teaching output.

6.1 Proxy Measures of Research Output

Universities' research outputs take various forms. Research outputs may ultimately be presented in the form of refereed journal articles, non-refereed journal articles, articles in weekly or monthly journals, review articles, book reviews, conference papers, books, dissertations, theses, project and consultation reports, public lectures, patents, software, exhibitions and others. The inputs in terms of time, and financial and physical resources vary from one research output to another. The quality of the outputs may also vary significantly, and not necessarily in direct proportion to the financial or physical inputs.

Verry and Davies (1976) used the number of articles and books published by a department's members as proxy for the annual research output of a university department in their study. They applied different experimental weights for books and articles published in journals regarded by academics as being of especially high quality.

Cohn *et al.* (1989) are of the view that ideally the various components of research output, such as publications, research reports, and other results of academic staff's research work should be measured. However, they state that such a measure is hard to produce for departments and universities.

Another view on the measurement problem of research outputs is that of Clayton (1987), who indicates in his report on the measurement of research expenditure in higher education that no progress has been made in the development of new measures for research outputs beyond the counting of research students supervised and the tally of publications. He is of the view that published output is the main external measure of research activity. However, he finds that the pattern of publication varies a great deal between different subject areas, and it is difficult to find a common measure. Clayton (1987) finally chose refereed papers as the denominator for working out unit costs of research, but he found, for instance, that engineering academics put lower emphasis on papers in refereed journals and greater emphasis on consultancy reports.

6.2 Surrogate Measures for Teaching Output

There are problems, too, of measuring teaching output. One of these is that of aggregating undergraduate, postgraduate taught and postgraduate research students into a single measure. The weights adopted in the UK are chosen fairly arbitrarily rather than based on an evaluation either of relative costs or of relative benefits. For instance in the research funding formula for 1991/92 the weights attached to undergraduates was 1, for taught postgraduates 1.2, and for research postgraduates it was 2. Such weighting could have been based on some concept of relative costs, but overseas students (be they undergraduates, taught postgraduates or research postgraduates) were given a weighting of 1 only. The use of this weighting was for deciding on funding and overseas students (their fees being on full cost basis) were given this weighting of 1 to have a neutral effect in the funding formula.

The main output of teaching activities is the production of human capital. Teaching outputs are not uniform. In the 1980s, there was a 20-subject group classification in the United Kingdom university system. In the 1990s, it had been changed to a 11-subject grouping with 37 cost centres. The teaching outputs of higher education institutions are usually expressed as degrees, diplomas and certificates of various kinds. There is also quality differentiation of the outputs in terms of class of honours. The inputs in terms of time, and financial and physical resources vary among the subject groups.

Bowen (1980), considers the full time equivalent student number to be a tenable measure for teaching output. Other measures of teaching output used are degrees conferred, understanding of the subject as measured by test scores, degree class or grade-point results, proportion of the entry that graduates, number of credit hours, etc. (Archibald 1974). Bottomley (1972), for example, used FTE student numbers as a denominator for calculating unit teaching costs at Bradford University. Verry and Davies (1976) considered various proxy measures of teaching output namely test scores, class of degree results, student numbers, student years of future graduates, and graduate equivalents but ultimately chose FTE student numbers.

7. Multi-Product Nature of Universities

Cohn *et al*. (1989) suggest that, with a few notable exceptions, cost and production analyses concerning institutions of higher education have been almost universally uni-dimensional, ignoring or assuming away the multiple-product nature of institutions of higher education. Estimation of the effect of size on unit costs has generally followed the assumption that the 'output' of institutions of higher education consists entirely of teaching, those of proxied by the number of FTE student enrolments. The uni-dimensional studies they refer to are those of Bottomley (1972), Bowen (1980), McLaughlin *et al*. (1980), and Maynard (1971). However, Brinkman (1981), Clayton (1987), Southwick (1969), and Verry and Davies (1976), among others, have treated universities as multi-product institutions. Glass *et al.* (1995a; 1995b; 1996) also treated universities as multi-product institutions

Baumol *et al*. (1982) indicate that economic theory focuses on single-product firms when in actuality firms are multi-product oriented. In the multi-product case, they state, there is no natural scalar quantity over which costs may be averaged. Baumol (1986) indicates that there is also no acceptable way to aggregate outputs or disaggregate costs in multi-product firms. So it is not generally possible to define the average cost corresponding to the firm's output taken as a whole or that relating to the output of any one of its products by itself. There is just no easy way to determine a denominator for the average cost figure. Nor is there any unique way to deal with the numerator in the average cost expression to apportion total costs among the individual outputs of the enterprise, permitting the calculation of a separate average cost, item by item. The firm's total cost includes some outlays attributable directly to particular goods in the firm's product line and some expenditure which is incurred for several such outputs jointly. Except by arbitrary convention, it is therefore impossible in general to divide up the firm's total costs in a unique manner, imputing every part of this cost explicitly to one or another of the suppliers' outputs. In practice, however, firms do assign common costs to specific outputs on some arbitrary basis. Verry and Davies (1976) and Clayton (1987) have chosen this pragmatic approach to work out unit costs of research and teaching outputs of universities.

8. A Composite Measure of Research Output

The lack of natural measures of research and teaching output has been noted. Researchers have tried to overcome the difficulties by the use of proxy measures. Proxy measures of teaching, such as full-time equivalent student numbers, are quite commonly used and do not pose real problems to researchers and are not so controversial.

In the case of research, the choice of one measure may preclude another and thus unit cost figures for outputs may not be comparable. For example, refereed articles may not be a clear indicator of research output in engineering departments, as more emphasis is put on consultancy. The 1989 Research Assessment Exercise Report (UFC 1989a) indicates that the findings of 'pure' science research are, to a much greater extent than for applied science, reported through publications. Thus the publications measure of research output may be biased towards the pure sciences and may for this reason show lower research output and therefore higher unit costs in respect of applied sciences unless this is allowed for specifically.

The problem with conceptualising and measuring research output is that though there are many indicators there is no single aggregate measure. The problem of aggregation with regard to multiple products applies to research, even more than to teaching. Refereed articles, consultancy reports, books, etc. cannot be added to get one aggregate measure of research output unless we can bring all of them into some standardised unit through the use of appropriate weights, as is possible with teaching outputs. The former University Grants Committee and Universities Funding Council and the territorial funding councils have organised at periodic intervals research assessment exercises. Their publications on research are focused on the rating quality aspects.

An approach to research activity (not output) measurement, albeit controversial, is to use a composite index measure which will take into account as many variables as possible which reflect research activity. Whittington (1994) offers some suggestions of a similar nature.

According to him postgraduates should be excluded from FTE student number counts and instead included in a separate measure of research output which includes publications, peer-group rankings, and research funds raised.

The composite index approach outlined here could be represented as a standardised level of research activity. It could epitomise all types of research activity, either directly or indirectly, through the various variables that have gone into its make up. Economists have used this concept to deal with the difficulties of multi-product output measurement. Composite measures of output are also often encountered in other service industries such as transport and health. The composite index measure developed below varies from those used in, say, transport in that it does not take into account physical measures such as kilometres travelled multiplied by tonnage carried, to arrive at a composite measure of output such as ton miles. In the method used in transport, a load of one ton carried for a distance of one mile is equal to a ton mile. The ton mile is one way by which different size loads and distances may be compared on a common unit basis (Pizzey 1989). The composite approach has now been used in a narrow way by Nevin (1985) and Glass *et al.* (1995a; 1995b; 1996). The composite index developed in this paper takes into consideration for each university institution the following: (i) the 1989 Research Selectivity Score Ratio; (ii) the UFC 1990/91 Research Funding Ratio; (iii) Research Postgraduate Student Numbers as a Ratio of Total Postgraduate Student Numbers; (iv) Arts Postgraduate Student Numbers as a ratio of Total Postgraduate Student Numbers (a minimum of 0.4 was assumed where the ratio dips below that, so as to avoid penalising science-biased institutions); (v) Academic Research Staff Numbers as a ratio of Total Academic Staff Numbers; and (vi) Research Grants and Contracts as a ratio of Total United Kingdom Research Grants and Contracts. The computation of all the variables mentioned above are straight forward except in the case of variable (i). The computation of this variable is explained below.

Five out of the six variables chosen are related to research performance indicators of a university. Variable (iv) Arts Postgraduates Ratio has been brought into consideration to reduce the strong bias towards the science-based institutions. At the same time the adverse effects of this ratio on the highly science-biased institutions have been reduced by assuming a minimum of 0.4 in the ratio. Without this variable, the results of the computation would lean rather strongly towards the older universities as they have higher ratios for most of the variables chosen. The inclusion of this variable brings about a relative activity indexation.

The ratings from the 1989 research selectivity exercise were used in the computation of the 1989 research selectivity score ratio (variable i). The score ratios under this RAE as well as that of 1992 and 1996 are given in Annex 1.

In the 1989 RAE, a total of 152 units of assessment were identified. The number of units of assessment varied from 1 (in the case of institutions such as LBS) to 90 (for London University). To obtain the 1989 RAE score ratio for each institution, the ratings achieved by each institution's units of assessment have been added and the sum converted to a ratio by comparing it against a total rating that could have been achieved if all the units of assessment were to receive the highest rating. Thus if an institution had four units of assessment and the ratings obtained by them were 2, 5, 3, and 2, then the total sum of 12 achieved by this institution is compared against the 20 maximum that it could have obtained if all were given a rating of 5. The score for this institution would thus be 0.6.

The composite measure of research activity is obtained by multiplying the six variables and converting the result into reasonable sized whole numbers to give meta-physical units of research activity. Under this approach no variable should have a zero value. Only for one institution (Lampeter) and in only one year was a zero value encountered. The problem was resolved by assuming a minimum value. The computation of the 1989/90 figures of research activity for United Kingdom universities in this research is given in Annex 2. The figures thus obtained are given the name hypothetical composite research units to avoid confusion. These figures are produced for the sole purpose of obtaining a relative research activity index and cannot be considered as a measure of research output. However, it is contended that a measure of this nature may be further refined to become a measure of research output.

9. Student Units as Measure of Teaching Outputs

The full-time equivalent student number has generally been taken as a proxy measure of teaching outputs in higher education. Under this concept, part-time students are converted into full-time equivalent status and added to the full time student numbers to obtain the proxy teaching outputs. Bowen (1980) modified the full time equivalent student numbers to student units by giving different weights to each level of undergraduate and postgraduate studies. This enabled him to make cost comparisons between different undergraduate as well as postgraduate years. This approach was also used in the development of the funding models in Australia and New Zealand in the late 1980s. In the Australian Model (DEET 1990) relative costs were used as the basis for developing the weights used in the calculation of their weighted equivalent full-time student units (WEFTSU). Subject disciplines were grouped into clusters. There were five clusters at the undergraduate level, three clusters at the non-research postgraduate level and two clusters at the research postgraduate level. Weights for undergraduates varied from 1 in the first cluster (Arts/Social Science) to a high of 2.7 in the fifth cluster (Clinical). The weights for non-research postgraduates similarly varied. The lowest weight was 1.4 and the highest 3.0. In the case of the research postgraduates, the weights were 2 and 4.7 respectively for the non-laboratory, and laboratory and clinical disciplines. In New Zealand, the teaching funding model involved calculation of equivalent full-time student numbers. For this, relative costs were used as in the Australian model. They had six subject cost categories and the weights for undergraduates varied from 1 (Arts/Social Science) to 6.81 (Dentistry). Research postgraduate students in the Arts and Social Science category were given a minimum weight of 2. The laboratory-based subjects had higher weights for such students (MOE 1991).

In this paper, the student unit concept is used to obtain a measure of teaching outputs for universities in the United Kingdom. The student units for each university are obtained by multiplying the full-time equivalent student load of each of its cost centre by its cost centre weight and totalling them up. The basis for the cost centre weights are the UFC 1991/92 subject units of resource. Weights are not given for undergraduate year of study or for postgraduate status as the UFC did not differentiate by year or status in its allocation of teaching resource, though it did use differential weighting for students in its research funding formula. It is thus assumed that there is no difference in resource consumption between undergraduate and posgraduate years of study. Differences are attributed solely to subjects of study. The 1991/92 units of resource (UFC 1991) and weights selected for each cost centre are given in Annex 3.

10. Conclusion

The composite research units and the student units computed in Annex 2 and Annex 4 respectively give an indication of the research activity levels and the teaching outputs of universities in the United Kingdom in the pre–1993 period. The composite research units indicate high research activity levels in the larger and older universities. For example, University of London has a Research Unit figure of 5,227,460. It is followed by Oxford which has a figure of 4,834,650 and Cambridge with a figure of 2,908,663. The other universities have much lower figures. This would suggest that relatively there was greater research activity in these universities compared to the other universities. Though the research activity measure developed here has its weaknesses such as the arbitrary adjustment done to reduce the bias in the computation towards science-biased universities, it provides a form of research index of universities in the United Kingdom in the early 1990s. Future research may help refine this measure though it has abstract properties in the way it has been developed to produce units of activity.

Student Units shown in Annex 4 also indicate higher levels of teaching outputs in the larger and older universities. London University has the largest student unit figures of 101,288 in 1989/90. It is followed by Manchester with a figure of 23,002. Glasgow has a figure of 22,454. Cambridge, Oxford and Leeds have relatively smaller figures compared to London, Manchester and Glasgow. The student unit figures take into account more variables and ought to give a more representative picture of teaching outputs. Its weakness is the element of arbitrariness in the assignment of the weights to some of the variables but this cannot be completely avoided.

The composite research units and student units are extensions to measures of university outputs. Though there are weaknesses in their formulation, they could be useful as denominators in average cost computations as long as the units are computed in a consistent manner for all institutions in a group.

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Annex 1: Research assessment scores

	1989	1992	1996
Aston	.46	.62	.59
Bath	.56	.75	.76
Birmingham	.60	.74	72
Bradford	.51	.55	.62
Bristol	.71	.72	.76
Brunel	.44	.60	.61
Cambridge	.88	.94	.89
City	.41	.61	.53
Durham	.62	.73	.69
E.Anglia	.63	.70	.64
Essex	.74	.75	.73
Exeter	.59	.69	.63
Hull	.53	.60	.58
Keele	.40	.57	.61
Kent	.54	.60	.59
Lancaster	.65	.75	.74
Leeds	.57	.69	.70
Leicester	.52	.66	.65
Liverpool	.60	.69	.67
L.Bus.Schl	1.00	1.00	1.00
London	.64	NC	NC
Loughborough	.54	.67	.70
M.Bus.Schl	.60	NA	NA
Manchester	.69	.74	.73
UMIST	.70	.78	.76
Newcastle	.58	.67	.65
Nottingham	.61	.73	.72
Oxford	.88	.90	.91
Reading	.60	.67	.69
Salford	.39	.56	.65
Sheffield	.65	.72	.74
Southampton	.64	.71	.70
Surrey	.58	.71	.69
Sussex	.60	.74	.73
Warwick	.83	.82	.77
York	.70	.73	.76
Aberystwyth	.52	.59	.58
Bangor	.49	.60	.57
Cardiff	.52	.62	.71
Lampeter	.40	.53	.47
Swansea	.52	.62	.64
U.W.Col.Med.	.70	.60	.60
Aberdeen	.54	.60	.60
Dundee	.46	.60	.61
Edinburgh	.65	.75	.71
Glasgow	.54	.64	.66
Heriot-Watt	.47	.61	.69
St. Andrews	.61	.73	.69
Stirling	.45	.64	.64
Strathclyde	.51	.65	.62
Belfast	.47	.56	.61
Ulster	.42	.60	.54

Source: Computed from the 1989, 1992 and 1996 RAE outcome publications.

Annex 2: Computation of hypothetical composite research units for 1989/90.

	Var. 1	Var. 2	Var. 3	Var. 4	Var. 5	Var. 6	HCRUs
Aston	0.4600	0.31	0.3339	0.5792	0.2282	0.0037	23476
Bath	0.5636	0.33	0.5320	0.4791	0.3112	0.0086	126544
Birmingham	0.6042	0.35	0.4041	0.5170	0.3223	0.0290	413353
Bradford	0.5053	0.30	0.4586	0.4945	0.2255	0.0073	56615
Bristol	0.7149	0.37	0.5465	0.4623	0.3769	0.0249	627483
Brunel	0.4381	0.30	0.3097	0.4942	0.3113	0.0073	45950
Cambridge	0.8800	0.44	0.7102	0.4938	0.4328	0.0495	2908663
City	0.4111	0.30	0.1268	0.7312	0.1538	0.0053	9404
Durham	0.6162	0.33	0.5468	0.6505	0.2995	0.0102	222054
E.Anglia	0.6308	0.35	0.4578	0.6324	0.2625	0.0083	139536
Essex	0.7375	0.38	0.4089	0.5796	0.2706	0.0062	111632
Exeter	0.5886	0.31	0.3085	0.7963	0.1856	0.0055	46084
Hull	0.5333	0.29	0.2729	0.7763	0.2031	0.0049	32312
Keele	0.4000	0.31	0.2924	0.6975	0.1826	0.0043	20016
Kent	0.5438	0.35	0.4529	0.6382	0.2460	0.0067	91131
Lancaster	0.6467	0.34	0.3687	0.7357	0.2376	0.0065	91541
Leeds	0.5714	0.33	0.4426	0.5060	0.2803	0.0230	272717
Leicester	0.5231	0.33	0.2881	0.6748	0.3687	0.0158	195909
Liverpool	0.6040	0.34	0.4862	0.4000	0.3112	0.0242	300653
L.Bus.Schl	1.0000	0.39	0.0852	1.0000	0.4268	0.0025	35600
London	0.6433	0.40	0.4214	0.4488	0.3910	0.2747	5227460
Loughborough	0.5385	0.31	0.3975	0.4000	0.3165	0.0111	93294
M.Bus.Schl	0.6000	0.28	0.1700	1.0000	0.2500	0.0007	5178
Manchester	0.6857	0.34	0.4453	0.5547	0.2678	0.0300	462183
UMIST	0.7000	0.40	0.5782	0.4000	0.3814	0.0162	399602
Newcastle	0.5787	0.35	0.4038	0.4000	0.3213	0.0211	221664
Nottingham	0.6082	0.35	0.4915	0.5091	0.3560	0.0210	398483
Oxford	0.8826	0.45	0.7761	0.6023	0.4072	0.0640	4834650
Reading	0.6049	0.35	0.3157	0.5473	0.2591	0.0135	127702
Salford	0.3909	0.31	0.4899	0.4000	0.1748	0.0047	19713
Sheffield	0.6526	0.33	0.4511	0.4904	0.2903	0.0193	266322
Southampton	0.6381	0.37	0.5559	0.4319	0.4103	0.0256	595416
Surrey	0.5818	0.35	0.3237	0.4879	0.4242	0.0142	193630
Sussex	0.6000	0.38	0.5197	0.6236	0.3467	0.0116	296720
Warwick	0.8250	0.38	0.3082	0.6544	0.3669	0.0181	420181
York	0.7048	0.36	0.3643	0.6751	0.4007	0.0106	264270
Aberystwyth	0.5185	0.32	0.2816	0.5161	0.2191	0.0040	21065
Bangor	0.4909	0.31	0.3702	0.4000	0.2899	0.0073	47534
Cardiff	0.5220	0.34	0.3463	0.5965	0.2456	0.0101	91113
Lampeter	0.4000	0.26	0.7317	1.0000	0.0263	0.0002	444
Swansea	0.5161	0.31	0.5398	0.4775	0.1935	0.0071	56424
W.C.Medicine	0.7000	0.35	0.3460	0.4000	0.4306	0.0098	142603
Aberdeen	0.5436	0.32	0.4831	0.4000	0.2970	0.0111	110531
Dundee	0.4560	0.31	0.4365	0.4000	0.3403	0.0123	103565
Edinburgh	0.6492	0.38	0.5535	0.4605	0.3289	0.0360	744543

Annex 2 continued

	Var. 1	Var. 2	Var. 3	Var. 4	Var. 5	Var. 6	HCRUs
Glasgow	0.5444	0.35	0.5089	0.4787	0.3463	0.0382	613856
Heriot-Watt	0.4667	0.33	0.4185	0.4000	0.3682	0.0113	107077
St. Andrews	0.6148	0.34	0.8238	0.4000	0.2482	0.0059	101261
Stirling	0.4476	0.30	0.2175	0.7618	0.2366	0.0039	20327
Strathclyde	0.5091	0.34	0.3743	0.4956	0.3323	0.0180	192004
Belfast	0.4708	0.27	0.3725	0.4892	0.2678	0.0106	65921
Ulster	0.4182	0.24	0.1565	0.7323	0.1124	0.0040	5185

Notes to Annex 2

The six variables are as follows:

Variable 1. 1989 Research Selectivity Score Ratio.

Variable 2. UFC 1990/91 Research Funding Ratio.

Variable 3. Research Postgraduate Student Numbers as a ratio of Postgraduate Student Numbers.

Variable 4. Arts Postgraduate Student Numbers as a ratio of Total Postgraduate Student Numbers. (A minimum of 0.4 is used where the ratio dips below this number. This is done to prevent penalisation of highly science-biased universities.)

Variable 5. Academic Research Staff Numbers as a ratio of Total Staff Numbers.

Variable 6. Research Grants and Contracts as ratio of Total United Kingdom Research Grants and Contracts.

Source: Computed from information in Form 3 Data and UFC Circulars (UFC 1990; UFC 1989b).

Annex 3: Cost centre units of teaching resource 1991/92 and associated weights

		Units of Resource	Initial Weights	Final Weights
1.	Clinical Medicine	9530	3.86	3.9
2.	Clinical Dentistry	10530	4.26	4.3
3.	Pre-clinical studies	5280	2.14	2.1
4.	Anatomy and Physiology	4480	1.81	1.8
5.	Pharmacology	4480	1.81	1.8
6.	Pharmacy	4480	1.81	1.8
7.	Nursing	4480	1.81	1.8
8.	Other studies allied to medicine	4480	1.81	1.8
9.	Biochemistry	4770	1.93	1.9
10.	Psychology	4770	1.93	1.9
11.	Other Biological Sciences	4770	1.93	1.9
12.	Agriculture and Forestry	4590	1.86	1.9
13.	Veterinary Science	9310	3.77	3.8
14.	Chemistry	5110	2.07	2.1
15.	Physics	5110	2.07	2.1
16.	Other Physical sciences	5110	2.07	2.1
17.	Mathematics	3000	1.21	1.2
18.	Computer Science	3880	1.57	1.6
19.	General Engineering	5180	2.10	2.1
20.	Chemical Engineering	5180	2.10	2.1
21.	Civil Engineering	5180	2.10	2.1
22.	Electrical and Electronic Eng	5180	2.10	2.1
23.	Mechanical, Aero and Prod’n Eng	5180	2.10	2.1
24.	Mineral engineering	5180	2.10	2.1
25.	Metallurgy and Materials	5900	2.39	2.4
26.	Architecture	4130	1.67	1.7
27.	Other Technologies	5180	2.10	2.1
28.	Planning	4130	1.67	1.7
29.	Geography	3020	1.22	1.2
30.	Law	2470	1.00	1.0
31.	Other Social studies	2470	1.00	1.0
32.	Business and Management Studies	3160	1.28	1.3
33.	Accountancy	3160	1.28	1.3
34.	Language-based Studies	3270	1.32	1.3
35.	Humanities	3110	1.26	1.3
36.	Creative Arts	3680	1.49	1.5
37.	Education	3820	1.55	1.5

Notes to Annex 3:
Computations:
The figures in respect of pre-clinical studies and humanities have been calculated as follows:

	Units of Resource	Student Numbers	Resource x Students
Pre-clinical Studies:			
Pre-clinical medicine	5210	8186	42649060
Pre-clinical Dentistry	5750	1250	7187500
Average\Total	5282	9436	49836560
Humanities:			
Archaeology	3710	1581	5865510
Other Humanities	3060	18460	56487600
Average/Total	3111	20041	62353110

Combination subjects units of resource have not been taken into consideration in fixing the cost centres' units of resource.

Psychology has been treated as a laboratory-based subject as done by the UGC/UFC since 1984/85.

In deciding on weights, undergraduates and postgraduates have been treated as equal, as done by the UFC in determining the subject units of resource.

Weights are calculated as follows:
The numerator is the cost centre's units of resource.
The denominator is the lowest cost centre units of resource.

Example:
Architecture is computed as 4130 divided by 2470 to yield 1.67 as the initial weight. The final weight selected for use in the computation of student units is a rounded figure, in this case 1.7.

Source: Circular Letter 6/91: *Recurrent Grant and Funded Student Numbers for Academic Year 1991/92,* 25 February, 1991, Universities Funding Council.

Annex 4: Student units

Name	84/85	85/86	86/87	87/88	88/89	89/90
Aston	6140	6073	5885	5824	5890	5969
Bath	6396	6316	6425	6599	7012	7256
Birmingham	15900	16036	16614	16699	17431	18859
Bradford	7325	7247	7479	7268	7692	8132
Bristol	12780	12956	13185	13588	13574	14341
Brunel	5252	5398	5672	5761	5823	5861
Cambridge	19665	20151	20543	20959	21530	22024
City	4966	5314	5245	5239	5184	5672
Durham	7268	7379	7565	7540	7700	7970
E. Anglia	5969	6204	6389	6351	6239	6749
Essex	4183	4299	4351	4476	4515	4980
Exeter	7086	7050	7209	7355	7838	8363
Hull	6837	6840	6972	7103	7272	8431
Keele	3756	3878	4064	4138	4485	4785
Kent	5569	5742	5915	6016	6218	6546
Lancaster	6238	6403	6541	6828	7092	7659
Leeds	18934	18758	18631	18309	19344	20947
Leicester	7681	7770	8034	8059	8529	9404
Liverpool	15698	15915	15821	15756	16021	17279
L. Bus. Sch	477	472	517	527	510	595
London	92755	90712	89563	91668	98322	101288
Loughboro’	8606	9075	8686	9262	9230	9578
M. Bus. Sch	322	337	360	377	423	451
Manchester	20452	20940	21014	21187	21509	23002
UMIST	7247	7213	7591	7721	7901	8611
Newcastle	14652	14827	15093	15177	15864	16360
Nottingham	12800	12987	13420	13547	13647	14407
Oxford	20022	20359	20671	20993	21171	21776
Reading	8742	8847	9174	9254	9436	11830
Salford	6734	6905	6992	7309	7061	7666
Sheffield	14339	14385	15105	15144	16014	16469
Southampton	11363	11352	11581	11689	12054	12637
Surrey	5805	5842	6154	6410	6697	7384
Sussex	6360	6786	6777	6556	6786	7668
Warwick	7791	8147	8522	9439	10073	10877
York	5138	5333	5612	5724	6061	6439
Aberystwyth	4310	4231	4501	4651	4674	5261
Bangor	4164	4419	4708	4775	4992	5441
Cardiff	12975	13776	13935	13477	13572	13450
Lampeter	905	922	950	936	1050	1106
Swansea	6060	6384	6876	7165	7092	8117
U.W.Col.Med	3063	2906	3000	2907	3065	3742
Aberdeen	9619	9707	10096	10139	10260	10687
Dundee	6335	6471	6618	6749	7093	7284
Edinburgh	18778	18879	18826	18731	19296	19747

Annex 4 continued

Name	84/85	85/86	86/87	87/88	88/89	89/90
Glasgow	20087	20830	21052	21402	21612	22454
Heriot-Watt	5036	5417	5433	5629	5846	6094
St. Andrews	5320	5427	5677	5694	5905	6068
Stirling	3873	3916	4385	4572	4718	4997
Strathclyde	12446	12630	12619	12748	13105	13605
Belfast	12403	12940	13267	13575	13844	14206
Ulster	14464	14629	14614	15124	15730	15794