Ashton Lee's *Review* CEER-X-227: EVALUATION OF CEER PRODUCTIVITY by Wallace C. Koehler, Jr. June 1988
CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

EVALUATION OF CEER PRODUCTIVITY 1979-80 TO 1987-88 by Wallace C. Koehler, Jr. June 1988

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EVALUATION OF CEER PRODUCTIVITY 1979-80 TO 1987-88

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Date: June 1988

Introduction

In recent years, much concern over productivity has been expressed in various circles, including government, private sector, and universities. A new awareness of the need to assess "white collar" as well as "gold collar" productivity has emerged. It is generally acknowledged that these productivity assessments are difficult to do, but they are necessary both for purposes of organizational control and for the improvement of innovation.

Recognizing this need, the Senior Advisory Committee (SAC) of the Center for Energy and Environment Research (CEER) recommended in its 1987 Report to the President of the University of Puerto Rico (UPR) that CEER "...develop performance and productivity indicators..."

This report undertakes to respond to the recommendation of the Senior Advisory Committee. It is a time-series study, beginning in fiscal year 1979/80 and extends to the present. The focus is primarily on CEER, its changing funding bases, and on output measures. Comparisons are also made with other research organizations as well as with three Colleges (Natural Sciences, Arts and Sciences, Engineering) of UPR.

As indicated below, productivity assessments are both qualitative and quantitative in nature. No satisfactory algorithm now exists to generate some performance index. Therefore, no...

An attempt is made to provide one. Each evaluator may provide whatever weight he/she deems appropriate to act. "Performance" or the factors which make up "productivity" assessments are often subjective. As stated in the Senior Advisory Committee's Report to the University of Puerto Rico President on August 20, 1987, "The evaluation of research productivity, value, and impact is a complex, if not impossible task. It is first necessary to define productivity. The definition and evaluation of productivity is a function of the purpose, role, and goals of any given organization or individual. Thus a research center, such as CEER, should not be compared to a manufacturing enterprise or to academic departments. Such comparisons could very well be deceptive, insofar as the function of CEER differs from manufacturers or from academic departments."

The typical academician has three "production" outputs: publications, teaching, and service. Promotion and reputation are based on a mix of these three factors. Publications are usually disaggregated as peer-reviewed, symposium proceedings and conference papers, and sometimes reports. Peer-reviewed publications are often perceived as more important than all others (with the exception of books, at least in some disciplines).

Another indicator, growing in perceived importance, are patents. Until recently, it had been difficult to patent work resulting from federal funding. As a consequence, there has been little or no incentives for CEER or UPR personnel to seek patents for their work. A survey currently underway by the Governor’s Adjunct Council on Science and Technology suggests that there have been few patents awarded to residents of Puerto Rico, and none are identified for CEER or UPR as a whole.

In any case, the importance of patents depends on disciplines and sub-disciplines. Some fields, by their very nature, are likely to result in more patentable work than others.

*Personal communication, Sandor Boyson, April 1988. The survey results are not as yet final.

Will others. CEER, however, is not an academic department. A different set of standards and measures are necessary to evaluate its productivity. CEER's mission is goal directed, and it is both an applied as well as a basic research center. A large proportion of its effort is funded by contracts with Commonwealth and federal agencies as well as private organizations. CEER scientists do publish in peer-reviewed journals, but they are also required by contracts to provide other deliverables. These other deliverables are often verbal and/or written reports to the contractor. Thus, CEER's output matrix differs, and should differ significantly from academic departments and, for that matter, manufacturing concerns or government agencies. Productivity is perceived and defined in a variety of ways. In general, it is presented as an Input/Output node. Given x resources, y products are produced in z time. The Virginia Productivity Center, located at the Virginia Polytechnic Institute and State University (VPI), sees productivity as one factor in defining “performance.” For them, "productivity measurement can be viewed as a device by which to monitor the system under study." Performance is assessed based on seven variables:

1. Effectiveness: doing the right things on time, and in the right manner, in terms of goals, objectives, activities, goods, products, services, etc.
2. Efficiency: the ratio of resources expected to be consumed on the right things to resources actually consumed.
3. Quality: conformance to specifications, fitness for use.

Asink, D. Scott, Thomas C. Tuttle, and Sandra J. Devries in "Productivity Measurement and Evaluation: What is Available?" in National Productivity Reviews, Summer 1984, p. 265.

4. Productivity: the ratio of quantities of outputs (goods and services) from an organizational system over a period of time to quantities of input resources consumed by that organizational system for that period of time, or, the ratio of quantity at the desired level of resources to resources actually consumed.

5. Quality of Work Life: This refers to the effective response or reaction of human beings to working and living within organizational systems.

6. Innovation: This is the creative process of adapting products, services, processes, structures, etc., in response to internal and external pressures, demands, changes, needs, etc.

7. Profitability/Budgetability: This is a measure or set of measures that assess the attributes of financial resource utilization.

In February 1986, the federal government implemented a program to increase productivity by departments and agencies. The definition given for productivity is: "The efficiency with which resources are used to produce a service or product at specified levels of quality and timeliness." This is a purposefully ambiguous definition and encompasses several of the factors defined by VPI. However, it can be a useful guide if appropriate definitions are adopted.

See also D. Scott Sink and Paul E. Rossler, "Performance Measurement and Evaluation: Who For, What For, Tools and Techniques," Virginia Productivity Center, PPS-3, 1987; Sink, "Much Ado

About Productivity: Where Do We Go From Here?" IE, October 1983.

'Executive Order of the President 12552, February 23, 1986, "Productivity Improvement Program for the Federal Government."

On Measurement: Federal department and agency heads were subsequently directed to individually establish guidelines, effectively defining "efficiency," "service," "product," "quality," and "timeliness." Explicit in the definition and subsequent instructions is the need to structure the assessment of efficiency or productivity in terms of the mission of departments, agencies, and their sub-units. Thus, the "amount of product and type of product" are a function of the goals and purposes for which the unit is established.

The federal government has found it difficult to establish generalizable guidelines for measuring productivity. To date, it has not extended these guidelines to federal GOCO (Government Owned, Government Operated) units.

The text refers to government-owned, contractor-operated (GOCO) laboratories. Enquiries to two DOE GOCO laboratories have established that the multipurpose national laboratories do not, in any formal fashion, attempt to quantitatively measure productivity because no legitimate methodology yet exists to do so. Oak Ridge National Laboratory does collect data on itself and selected other laboratories. These data are periodically published to assist management in making assessments. Data from ORNL Indicators, 1987, the latest set, are presented below.

DoD government-owned, government-operated (GOGO) laboratories have attempted to quantify productivity, but these methodologies have come under criticism both internally and externally. The National Institutes of Health have utilized bibliometrics to track the "quality" of work resulting from their grants and as a tool for grant-making decisions (more information on methodologies follows).

Interestingly, the National Science Foundation, in its biennial Science Indicators, does not publish data on scientific productivity as such. One indicator of research productivity, the economic impact of private sector R&D can and has been demonstrated at the national level of analysis. The same has not been established for most government-sponsored R&D because of its usually basic nature.

The federal government and its laboratories have found it difficult to quantify productivity. The same holds for for-profit and not-for-profit "think tanks." Staff of two "think tanks," SRT International and the Institute for Energy Analysis, acknowledge that productivity assessment is desirable, but both indicate that they know of no quantifiable method to do so.

This information was gathered from sources including an Office of Management and Budget Bulletin No. 86-8 (February 28, 1986), a telephone interview with the Federal Productivity Resource Center (March 1988), and telephone interviews with Ronald Lohrding from Los Alamos National Laboratory, and Thomas Wilbanks and Beverly Wilkes from Oak Ridge National Laboratory (March 1988).

"The first such attempt was in 1917, and the work by F. J. Cole and B. Beales in Science Progress remains relevant today. However, citation counting has its limits. By the mid-1960s, researchers sought a means to depersonalize the evaluation process. The advent of ASI's Science Citation Index, and the subsequent Social Science Citation Index, provided databases which can be analyzed. For further reference, see Alfred H. Schainblatt's "How Companies Measure the Productivity of Engineers and Scientists" in Research Management, 27 (May 1982), p. 10. Also, consider Richard Pappas and Donald Rener's "Measuring R&D Productivity" in Research Management, 7 (May 1985), and Michael B. Packer's “Analyzing Productivity in R&D Organizations," in Research Management, 31 (Jan-Feb. 1983). Packer suggests "output mapping" as a tool for subjective assessments. Francis Narin's "Bibliometric Techniques in the Evaluation of Research Programs," in Science and Public Policy, 14, 2 (April 1987), pp. 99-100, is also insightful.

These resources facilitate computer-aided methodologies. The indices permit counts of publications, citations, researchers, and their locations. Co-authorships could also be managed. Bibliometrics was developed to assess and map the sources of significant contributions to the scientific process. It concerns itself with where articles are published and which journals are most frequently cited. The fundamental assumption is that those journals which are most frequently cited are the most influential in any field or sub-field (this assumption contains at least the seeds of tautology). Since citations are retrospective, they measure work which was performed and published in the past; they are not a measure of the current importance of a body of work. It takes between two and six years before a published article is cited in other published articles. However, it is possible to count the number of current publications, by authors, departments, universities, states, nations, in the not-so-important to the very-important literature. Those currently publishing in..."

The "important journals" are, as a priority, publishing the most influential work. Bibliometricians are quick to stress, however, that these comparisons must only be made among units in the same fields, performing similar functions. Indeed, these comparisons should perhaps be limited to sub-fields, because the publication practices of disciplines and sub-disciplines differ, and because field and sub-field perceptions of which journals are important, etc., differ. Finally, some "knowledge products" are books, reports, proceedings, papers, and theses. As no bibliometric track record exists against which to assess the probable impact of the Office of Technology Assessment, these "knowledge products" do not count.

It should also be noted that the advent of electronic mail, as well as the traditional "cloak room" transfer of scientific innovation at meetings and conferences, diminishes the impact of published "knowledge products," at least in certain areas. There is anecdotal evidence, for example, that the recent advances in superconductivity - resulting in Nobel Prizes - gained little from the published literature; the advances were too fast, publication times too slow. Certain advances in biotechnology underwent a similar experience. For a bibliometrician, these "knowledge products" would also not "count". Comparisons between academic departments and applied research centers are difficult, because organizations performing applied research, by their very nature, will produce fewer publications per capita than will their theoretical counterparts. Again, because of their nature, applied research centers will not score so well on bibliometric scales because their "knowledge products" are sometimes proprietary. Much of their work is published as reports, the required deliverable product of the research contract, and therefore are not "rated." Applied research centers with policy orientations, furthermore, are less likely to produce work. Francis Narin, President, CHI

Horizons, Inc., in a telephone interview in March 1988, concedes that reports are impossible to handle with the current methodology, as no quality stratification is possible. While books could potentially be stratified, it is extremely difficult to do so. Therefore, he does not attempt to measure either. A. Anderson, in "Research Gradings Stir Emotions," Nature, 322 (July 24, 1986), agrees. OTA, in their work (op cit, p. 40), and Narin, (op cit, D 100), also touch on this issue.

Peer-reviewed publications, as well as total "knowledge products," are difficult to assess due to the nature of the effort. Carpenter et al caution further that bibliometric techniques probably do not produce statistically significant results for units producing fewer than thirty publications per year per field or sub-field. With the possible exception of the Department of Physics at UPR, Rio Piedras, no field at UPR consistently produces peer-reviewed "knowledge products" at that level. If disaggregated by sub-fields, no UPR sub-unit has an adequate peer output for statistical measurement and assessment.

An Office of Technology Assessment study stresses these points, as well as stating that any bibliographic index is a "rough" indicator of the productivity of a program or facility. Finally, the OTA Memorandum asserts: "knowledge is produced by scientific communities, not individual institutions. Therefore, comparing facilities may be an empty exercise [emphasis added]."

It is clear that there are no acceptable quantitative, non-subjective methodologies to measure scientific productivity. Indices can be used, but they must be used very carefully. If comparisons among units are being made, care must also be taken to ensure that the index numbers were generated in exactly the same fashion, using the same assumptions, and that those assumptions are explicitly stated.

If the units being compared are from Stuart Nagel's Contemporary Public Policy Analysis (U of AL Press, 1984), see also American Council of Voluntary Agencies for Foreign Service, Inc., Technical Assistance Information Clearing House, and Approaches to Appropriate.

Evaluation: A Report on a Series of Workshops on Evaluation, (Washington, DC, 1978). Carpenter, F. Gibb, M. Harris, J. Irvine, B. Martin, and F. Marin, "Bibliometric Profiles for British Institutions: An Experiment to Develop Research Output Indicators," Scientometrics, in press. HOTA, op. cit, p. 40, quote at p. 36.

If institutions are not alike, then extreme care must be taken in assessing their knowledge productivity. Most studies conclude that assessment of productivity is necessary and desirable, but as shown by the preceding, it cannot be done by numbers alone. Instead, a Delphi process is usually called for, sometimes utilizing in-house personnel, at times outside personnel to make evaluations based on their expert perceptions of unit productivity. This function is performed by CEER’s Senior Advisory Committees (SAC). The Committee meets annually to evaluate CEER programs, following presentations by the programmatic groups. It has been policy that the SAC be balanced to reflect the two general foci of CEER, energy and environment. The SAC, in turn, prepares a report to the President of UPR, to which CEER responds.

One can turn for guidance into the "non-objective" evaluation process by considering the approach taken by those generally perceived to be successful. SRI International uses categories or guidelines which incorporate most of the processes appropriate for measurement of a research center. They are presented in alphabetical order, no fixed weight is given or implied. Evaluators can then balance their importance. These are:

- Ability to adapt to changing market conditions (Flexibility)
- Ability to attract people with strength
- Marketability: doing the same thing for more people and/or doing different things for the same people over time
- Number of papers, reports, and articles produced
- Reputations of staff members

Personal communication, Richard Marciano, March 1988. Marciano argues that for "research product numbers," it is important to remember that "qualitative drives quantitative."

The performance of the mission, therefore, entails an array of outputs or products, some of which are difficult to quantify. One reason for this is that the "product" itself varies from basic research findings to product or process engineering. Therefore, care must be taken in evaluating and/or comparing one type of output against another. Furthermore, the purpose or mission of any institution may vary from that of another; indeed, missions may vary within institutions or

Missions may change over time. This is true for CEER, as it transitions from a DOE GOCO laboratory to a service and research institution of the University of Puerto Rico. Additionally, changes in the funding environment can impact and alter programs. CEER has undergone a significant redefinition of its energy programs due to changes in federal policy. The DOE's stance on renewable and international programs has shifted from enthusiasm to apathy. As a result, several programs at CEER have had to be eliminated or reduced, notably OTEC and solar energy.

However, CEER has recognized that opportunities for growth exist in new programs and has established what appear to be viable new programs in solid waste management, remote sensing for resource management, and social science survey research. The biomass program has been reborn. Established programs such as marine and terrestrial ecology continue. Changing research agendas require time and retooling. Consequently, one must expect reductions in "research products" during periods of transition. Publications cannot be generated from programs undergoing start-up. The demands of start-up also reduce the time available to scientists to wind down and appropriately mine "old" research; as does the necessary process of writing new grants to fund new projects.

Furthermore, CEER is both a service and research organization. Started in 1979, the Summer Science Student Program was expanded from one to three groups in 1986. A further expansion to seven is anticipated for the 1988 Summer program. It will serve more than 200 students. The SSSP provides economically disadvantaged, but academically gifted high school students between their junior and senior years with science education. Through this program, CEER has a direct presence in the science education process of the Island. The University-Industry Research Center in Pharmaceutical / Chemical Sciences, funded by private industry, the National Science Foundation, The Puerto Rico Community Foundation and UPR are products of a CEER initiative, and CEER continues to provide administrative services to the Center. The Center aims to support university research in response to the needs of the industry. Originally conceived in September 1983, it was formally established in January 1987. To date, the Center has awarded six research grants to faculty from Island universities, focusing on areas of interest to the chemical and pharmaceutical industries. Most recently, CEER received a grant from 00E under its Minority Educational Institution Assistance Program to facilitate energy research at UPR. The program, titled "Infrastructure Support to Assist the Development of Energy Research," is funded for two years.

Neither the ISADER nor the Industry/University Center will generate research for the sake of research for CEER. They will also not generate any "research measures" for CEER. However, both may catalyze "knowledge products" throughout the University. CEER is also a user facility. It is part of the Oak Ridge Associated Universities faculty and student DOE laboratory. It is recognized that a science and technology-educated populace is crucial to economic development. Hispanics, among them Puerto Ricans, do not participate in scientific activities nor seek education in science at the same rate as their share of the US population might suggest. For reference, see the American Association for the Advancement of Science, Puerto Ricans in Science and Biomedicine, AAAS Publication 81-R-5, Washington, DC, November 1981. See also the San Juan Star, March 20, 1986, p. 4.

CEER is part of the fellowship program of the Oak Ridge Associated Universities. Each summer, ORAU sponsors and CEER hosts faculty and graduate and undergraduate students from mainland and Island universities. CEER also maintains a research facility at El Verde in the Caribbean National Forest. For a nominal charge, scientists performing research in the rainforest are housed and can use the CEER laboratories. Over the past five years, the average number of non-CEER researcher days by faculty and students at El Verde has been substantial.

The numbers for Verde have been 172 and 268, respectively. Research at El Verde has resulted in at least 45 peer-reviewed publications over the same period, many of which CEER receives no “credit” for. CEER personnel consult with government and the private sector, serve on boards, teach classes at UPR, and perform research and other services often on a pro bono basis. The results of these activities may not be classified as “research products," but they are a clear service to the community.

Programs like ISADER, which are funded, may in fact depress CEER’s “research indicators." For instance, they increase the CEER budget, thereby reducing the apparent output of "research products" per dollar. The services provided pro bono by scientists need time, time that might be spent doing other things. This also reduces the apparent output per scientist engaged in the policy process.

CEER produces three basic types of written "products." These are (1) reports, (2) peer-reviewed journal articles, and (3) non-peer reviewed articles, proceedings and/or conference papers. Reports and conference papers are often also published as CEER documents. The determination of what research shall be published in what form depends in part on contractual agreements. Contract research requires reports, therefore in these cases, reports are automatic. The decision to publish in peer versus non-peer reviewed journals can depend on the target audience. If one, for example, seeks to reach a largely Caribbean audience with general interests, there are few, if any vehicles to meet that need. This is particularly true in policy-related areas, where findings may have time-value.

Organization size is another factor which must be taken into account. CEER is a small operation. There has been a tendency in recent years, particularly for energy projects, to move from one large project to another. To date, as one project winds down, another begins, sometimes with gaps. OTEC devolved, the Integrated Energy Daisy Farm project emerged. The work at Juana Diaz was completed.

How many published "research products" have resulted from Juana Diaz? A search in several databases through Dialog for 1986 found none, while the Frengy Research Abstracts show three. Currently, the major energy project is the Aguirre bagasse program. It will be some time before published "research products" result from the Aguirre project; nevertheless, it has large-scale manpower demands. The same can be said of the Solid Waste Management Program. The CTS Index for the same year lists Resources. Resources are inputs in the "productivity equation." An examination of resources available is necessary. There are essentially three types of resources to be considered: (1) physical -- buildings, laboratories, equipment, etc., (2) funds, and (3) manpower availability.

Physical Resources: Since 1979, there have been major changes in physical resources available to CEER scientists. Staff sizes at Rio Piedras and Mayaguez have fluctuated, resulting in some strains on staff office facilities at Rio Piedras. Laboratory space has been converted, for example, to house the Industry/University Center, and the small conference room has been converted into office space. The research site at Cornelia was closed down. A major change in equipment is the proliferation of microcomputers, which presumably enhances scientist productivity.

Funds: The CEER funding base provides a complex picture. As already indicated, not all funds listed in the budget are designated either directly or indirectly for research functions. An increasing proportion of non-discretionary funds are assigned to service, as shown in Figure 6. Since FY 1979-80, CEER's funding has shifted and has been at times uncertain. As shown in Figure 1, CEER's funding peaked at almost $5 million in 1981-82, fell until 1985-86, when the trend was reversed. While the provisional FY 1987-88 budget has returned to approximately what it was in 1979-80, it is a third lower in real terms. Not only has the budget undergone change, the sources of funding have also evolved.

The text has been significantly changed. (Fig. 2) As Figures 1a and 1b show, not only did the source of institutional base funding shift entirely from DOE to UPR, but UPR's institutional funds are approximately half of what DOE base funding was. There was a significant downturn in competitive funds from 1981-82 to 1985-86. Figure 2 plots the funds CEER receives from UPR. Base funding has stabilized and is essentially flat. CEER also performs research and service for UPR, for which it receives competitive funding. A large proportion of the decline in competitive funds can be explained by shifting DOE priorities.

CEER UPR FUNDS Graph 1987-88

Due to institutional flexibility and the development of new programs, competitive funds have increased significantly in the last two years. The decline in the DOE competitive budget is explained, in large part, by the Reagan Administration's deemphasis on both renewable energy and environmental programs. In recent years, competitive funding from federal agencies other than DOE, ELA agencies, and private foundations and firms have become important sources of CEER research and service funding. For example, an expansion in the service budget is anticipated as the ISADER and SSSP programs expand. Keep in mind that no CEER research is funded by these monies.

Historically, CEER – as its name implies – has been divided into two major programmatic areas: Energy and Environment as well as Service. All three divisions have shared the impact of the decline in federal funds. The Environment group has had modest success in attracting non-government funding. The Service group, particularly SSSP, has increased private sector contributions significantly. It is noteworthy that in all three cases, federal funding has begun to increase. With the exception of Energy, ELA funding has declined. However, the Municipal Waste Program funding is not reflected here, nor are new or pending contracts with PRASA, PREPA, and PROE. This leads...

To an important conclusion. The dependence of CEER on UPR funds for its research and service programs has declined in relative terms over the last three fiscal years. However, this also underscores the need for base funding for an organization such as CEER to weather changing funding tides, and to overcome these changes in order to redirect its research and service programs efficiently. Without UPR base funding, an organization the size of CEER, with a dedicated mission, would flounder in an uncertain or changing environment.

Personnel

It may seem redundant to assert that for a research organization to produce “research products," it must have a research staff. Figures 3 and 4 provide data on scientific employees at CEER. These figures reflect “scientific staff" only. Those employees who only have administrative responsibilities are not included in this data set or any other point in the analysis. The number of Ph.D. and Master’s level scientists has remained relatively stable over time. The same is true of Ph.D. level consultants, although there has been some fluctuation in Ms, BE level consultants. The role of consultants has changed somewhat since the "changeover" from DOE to UPR base funding. Now, consulting is conducted on a more short-term basis than it was in the past. Thus, while data are not available as of this writing to substantiate the conclusion, the number of "FTE" consultants is probably down. While there has been relative stability in employee numbers, their distribution among programs has varied significantly, particularly in the energy division. The relative stability in funding for the environmental group is reflected in the relative stability of the personnel count. Funding instability and new energy programs have led to significant variations in personnel assignments. It should be noted that these changes do not necessarily represent new hires or fires; much of it is staff "changing hats." (Fig. 3) (Fig. 4) The term "consultant" is administrative. Several categories of...

The following associations are implied: adjunct scientist, part-time scientist, as well as part-time administrator. See page 23 for a more extensive definition.

Figure 9

Figure 4

CEER PROFESSIONAL STAFF By Conta A rs & “0 SS x0 KS \ . wn ZZ , ST yorto amy wie mas ayaa eyes sys wee 8 Me Sm om SI owe

Man, Money Match

The funding picture at CEER has been fluctuating, while the scientific staff size has remained relatively steady since FY 1979-80. The amount of money available per scientist is also an important consideration. See figure 5. Remember that these figures do not reflect the sum available for the direct funding of research, but include overhead administrative costs, physical maintenance, purchases, salaries of all personnel, service functions, utilities, and all other costs associated with the institution.

(Fig. 5) Figure 5 charts the level of total CEER funding per Ph.D. scientist, as well as per capita Ph.D. share of DOE and competitive and UPR base funding.

Research Output

Statistics can be misleading. Data are presented in this report in two forms. They differ in the way in which they are calculated. A more rigorous, conservative approach, which follows in the next section, is adopted for purposes of internal comparisons of CEER "knowledge product" productivity over time. CEER productivity needs also to be compared with other units of the University as well as with other similar organizations. Because of the extreme difficulty in acquiring outside base data sets, from which complex matrices could have been built, the second set of CEER data are calculated in the same fashion as other data appear to have been calculated. Assumptions for both approaches are stated in both analyses.

NOTA BENE: Again, extreme care must be taken when comparing inter-organizational data. The numbers can vary greatly according to

Figure 3

calculation assumptions. By way of example, compare Tables 1 and 3. Both appear to measure the same thing: the

The number of CEER publications is not included in Table 1. However, Table 3 does include this information, while Table 2 only counts the total share of publications by CEER associated Ph.D.'s. Publications by individuals at the Master's level and below, including ABD's, are not counted. The same caution applies when interpreting Tables 2 and 4. Tables 1 and 2 measure the "knowledge product" productivity of Ph.D.'s associated with CFER, based on the stated set of assumptions.

Tables 3 and 4 measure the total CEER "knowledge product" output.

Figures 6(a) and 6(b) graphically illustrate the difference between the "complex" and "simple" methodologies. These two methodologies have been used in the analysis of CEER output. The "simple" methodology reports total publications, disaggregated by type of publications, as listed in the Annual Reports for each year. The "complex" methodology calculates the share each author(s) has in each publication. This allows for an assessment of publications by degree held, by division, and so forth. The complex methodology is only appropriate for internal comparisons among divisions, per year, etc. The simple methodology is employed due to the lack of data for comparisons between or among organizations.

Assumptions for Ph.D. Count Only:

1. The FY 95/86 Report creates the first assumption problem: the employee list and the publication list are for two years. There was some difficulty in disaggregating publications and allocating them to the appropriate year. The solution adopted was to assign those publications with a 1985 publication date to FY 85/86; those with a 1986 date to FY 86/87. Inquiry indicated that one new Ph.D. was added between those two years, thus the Ph.D. count for FY 85/86 is 14, for FY 86/87, it's 15.

2. A productivity evaluation of any research organization can be made at three levels: institutional, by divisions, and by individuals. Individual evaluations, based on the publication record, are “easier” insofar as...

A "simple" vita count can be done. However, if one were to aggregate all such counts, multiple counting of articles would occur. This is because CEER publications sometimes carry multiple authorships, as many as eight. To correct for that, the basic matrix upon which these numbers are based allocates proportional credit to individuals. If you had one co-author, you would receive credit for 0.5 publications, and so on. This allows for a careful analysis at the institutional level, and with some adjusting, to the division or other level. The institution thus receives one credit per paper, less those excluded as explained in (3)(a)(i) (refer to the discussion on "simple" versus "complex" methodologies above).

CEER has three general categories of "associates." (a)(i) Employees and staff. CEER employees include PhDs and equivalents ("terminal professional degrees: MD, MBA, LLB/JD), Masters’ level, Bachelors level, and non-degree holders. All of these are indicated as direct participants in the research process. A number of Masters level scientists have publications to their credit.

Academic departments usually do their vita counts based on PhD "hits." Therefore, the logical approach is to count publications by PhD’s only in the employee category. Thus, the "complex" figure for CEER employee publications is the total of "fractional publications" by CEER staff PhDs divided by the total number of staff PhDs. Excluded is credit for publications by CEER staff at the Masters level or below. If Masters level scientist credit is given, then one must determine whether to include all Masters level scientists, or only those who publish in subsequent calculations. This also forces me to undertake additional complex spreadsheet manipulations over an immense matrix. Something about diminishing returns.

(ii) Appointments of CEER PhD staff differ. Some are full-time, others have dual appointments. Over the years, the time allocations by these people vary. Others are part-time. The most conservative approach is to weight their participation equally to their full-time counterparts.

Colleagues, it was as such. The "institutional memory" might be insufficient to handle each case appropriately in any event.

(b) Adjunct Staff and Consultants: CEER has diverse functions and maintains research and other contacts with a significant number of individuals. These people are listed as Adjunct or Consultants in the Annual Reports. Some fulfill non-research roles. The contributions of the adjunct staff to the publications were also "fractionalized." Only the adjunct staff who published were considered as "research adjunct staff" and included in the denominator. The totals and number of research adjunct staff are shown in Table 1.

(c) Co-authors: Even though they are not included as adjunct staff, several individuals were recognized for their contributions to CEER publications, peer-reviewed and otherwise. Most of these individuals are co-authors with CEER Scientists. Their contributions were likewise fractionalized. The totals and number of co-authors are shown in Table 1.

4. CEER "research products" are categorized as (i) peer-reviewed journal articles, (ii) papers and proceedings, and (iii) reports. How do we prioritize one over the other? Keep in mind that CEER research is often contract research, unlike research supported by a grant. The deliverable for contract research is the report to the contractor. In the case of CEER, these reports are often complex, requiring immense professional contributions. We also considered peer papers. In Tables 1 and 2 below, "peer publications" are those articles reported in the Annual Reports as published, excluding those marked as "in press." The figure for TOTAL includes everything reported, including those marked as "in press" or "submitted."

Adding these gives an indicator of total Ph.D. research scientist output, by association to CEER, as shown in Table 1:

TABLE 1. "COMPLEX" METHODOLOGY TOTAL PUBLICATIONS BY CEER PHD PERSONNEL

YEAR	CEER	ADJUNCT	COAUTHOR	PEER
79/80	15.5	0	0	10.7
80/81	2.6	12	2	6.5
81/82	5.5	25.1	0	3.40
82/83	4.7	51.4	6.9	21.8
83/84	5.3	40.6	1.8	8.5
84/85	15.2	74.2	-	-

The text is quite complex and seems to be a combination of various data points, research findings, and conclusions. Here's my attempt to correct it:

"The measure of publication productivity is generally given in per capita terms. Table 2 provides these data for each category of CER research personnel (CEER PRD's, Adjuncts, Coauthors). Again, the most conservative assumptions were made. An additional assumption is alluded to above: the treatment of part-time and other associates and their weighting as FTE’s. For the sake of the conservative parameter, all CEER PhD’s, as well as all adjunct researchers and coauthors were weighted equally when included in the denominator. Equally, no attempt at weighting in terms of research time available per scientist was made, even though many CEER scientists have dual or triple responsibilities.

TABLE 2. "COMPLEX" METHODOLOGY AVERAGE ANNUAL PUBLICATIONS PER CEFR ASSOCIATED PHD EY PEER TOTAL

79/80	0.	0.673
80/81	0.237	0.565
81/82	0.285	0.934
82/83	0.523	1.760
83/84	0.339	1.113
84/85	0.832	1.676
85/86	0.643	0.659
86/87	0.616	1.052

Source: CEER Annual Reports

As shown above, the past decade was a cyclical one for CBER’s funding. That is a function of the changing funding environment and of the size of the institution. CEER undergoes frequent project start-up and project terminations, particularly on the energy side: e.g. OTEC, Juana Diaz, Aguirre. These are costly in terms of “research products," particularly for peer-reviewed articles in as much as CEER staff must rededicate their efforts to the development of new programs. The writing of contract and grant proposals is not included in the count. Figures 7 and 8 break out CEER publications by the association of the authors to CEER. CEER staff predominate, but adjunct and non-adjunct authors contribute significantly. This is to be expected in an organization which serves as a user-site as well as a research facilitator. Note that these figures were built using the “fractionalized scores." (Fig. 7) (Fig. 8) Assumptions for Total CEER As"

Please provide more context or complete sentence for the last line "Assumptions for Total CEER As" to be able to correct it.

As discussed in the introduction, CEER scientists essentially produce three types of "research products". These are:

(1) Reports: Articles, proceedings, conference presentations.

(2) Peer-reviewed articles/books.

(3) Non-peer-reviewed articles/books.

This data set consists of the total number, in absolute terms, of publications, by type, reported in the annual reports. Publications with multiple authors are counted only once. The creation of this data set is necessary for comparisons with data from other organizations and because it is the most common approach.

The preceding was an analysis of CEER doctoral level "knowledge product" output, but not of the entity itself. Figure 9 shows the total number of CEER publications, as well as a breakdown by type from FY 1979-80 in absolute terms as reported in the annual report. Data points for peer-reviewed articles and proceedings were not reported in the annual report until the years indicated in the figure.

The general trend over the decade is an increase per year in the number of peer-reviewed articles published, coupled with a decrease in the number of reports (Fig. 9). The fluctuations in the number of conference proceedings and papers result from two phenomena: firstly, the relatively small size of CEER and, secondly, the number of international meetings in San Juan in any given year. CEER scientists took advantage of no-cost travel to make presentations, thus the perturbations.

A more sensitive measure is the number of publications per scientist. Figure 10 shows the number of publications per year per Ph.D., while Figure 11 includes in the calculation, MS level scientists as well (Fig. 10) (Fig. 12). Additional data are provided in Tables 3, 4, and 5.

For example, in FY 1984-85, among these were the Energy in the Americas Conference, Caribbean Studies Association Meeting, the Caribbean Islands Water Resources Congress, Association of Island Marine Laboratories Meeting, Congreso de Investigacion Cientifica.

Tropical Hydrology Symposium, Inter-American Congress of Chemical Engineers, and the Inaugural Meeting of the American Association for the Advancement of Science, Caribbean Division.

Table 3. "SIMPLE" METHODOLOGY TOTAL CEER PUBLICATIONS

FY	REPORTS	PAPER	PEER	TOTAL
1979-80	33	NA	NA	33
1980-81	36	NA	27	53
1981-82	24	NA	21	45
1982-83	31	NA	24	203
1983-84	22	29	23	80
1984-85	19	50	46	15
1985-86	15	83	36	93
1986-87	18	35	28	61
Mean=	24.6	37.0	28.7	72.9

Source: CEER Annual Reports

Table 4. "SIMPLE" METHODOLOGY AVERAGE NUMBER CEER PUBLICATIONS PER STAFF PH.D.

FY	TOTAL	PEER	REPORT	PAPER
1979-80	1.3	NA	1.3	NA
1980-81	2.9	0.8	2.0	NA
1981-82	3.10	1.4	1.5	NA

1982-83	6.9	1.0	2.0	3.2
1983-84	8.4	1.6	8.2	NA
1984-85	7.2	2.9	1.2	3.1
1985-86	6.2	2.4	0.9	2.9
1986-87	NA	1.5	8.2	1.0
Mean=	4.5	1.4	2.4	NA
Std. Dev.=	1.96	0.60	0.38	0.89

Source: CEER Annual Reports

Table 5. "SIMPLE" METHODOLOGY AVERAGE NUMBER CEER PUBLICATIONS PER STAFF PH.D. AND MASTERS LEVEL

FY	TOTAL	REPORT	PAPER	PEER
1979-80	0.9	NA	NA	0.9
1980-81	0.6	NA	0.3	1.3
1981-82	0.7	NA	0.6	NA
1982-83	0.9	1.5	0.7	2.7
1983-84	0.7	1.0	NA	NA
1984-85	0.7	1.0	1.0	3.4
1985-86	0.5	1.5	8.3	NA
1986-87	2.13	0.7	0.6	1.0
Mean=	2.3	0.7	1.3	0.9

Source: CEER Annual Reports

With the exception of papers, total "publication production" has been fairly consistent over time. CEER "Knowledge Product" Productivity over time is a function of both manpower and dollar inputs. Figure 12 is a graph of the total number of CEER publications per Ph.D. scientist per current and real dollar of the total CEER budget based on the "simple" count. Figure 13 is a plot of peer-reviewed papers per CEER Ph.D. based on the "complex" counting methodology.

It must be reemphasized when considering these findings, that the conclusions are focused on the institution, and not on individual scientists. For example, the publications data are a count of total output by CEER, and no count was made for purposes of this analysis of the output of specific individuals.

Do so would 28.

(Times 10 6-8) Figure 12.

Peer pubs by CEER PhD per dollar.

Rendering analysis difficult, given multiple authorship and staff turnover. This analysis suggests that (1) a reversal in the downturn in CEER external funding is occurring; (2) that UPR base funding provides an institutional anchor allowing the organization sufficient flexibility to respond to changing environments; and (3) that CEER scientific productivity, as measured in terms of peer articles, papers and proceedings, reports, and total output has tended to increase since FY 1979-80.

The analysis also suggests that since UPR base funding began, CEER has established a "research product band." That is, the institution has produced between 80 and 115 total publications per year, of which 28 to 46 were published in peer review journals and 18 to 22 were reports. The band for total publications would tighten if one were to correct for the "perturbation" in papers and proceedings discussed above. Given the fact that Marine and Terrestrial Ecology are soon to publish books, one can anticipate that the publication count will rise in this fiscal year.

Comparison CEER/other Centers.

In order to reach a meaningful conclusion on CEER productivity, it is necessary to compare like data with other similar each article/paper/report was counted once. An article/paper/report with one author is weighted equally to another with more than one author. Serious methodological problems must be overcome before "vita counts" can be performed.

Research/service institutions. Several similar research centers - those with an energy and/or environment theme, maintaining in-house research staff and facilities - were approached. These include: Energy, Environment, and Resources Center (EERC) , University of Tennessee, Knoxville. Data are not collected, no annual report published - per telephone interview (pti). Florida Solar Energy Center. Annual report contains no staff or publications count data.

The Hawaii Natural Energy Institute's annual report does not contain staff or publications count data. This institute functions primarily as a networking center. The Institute for Energy Analysis, which was associated with Oak Ridge Universities, is now closed and is currently managed by the EERC. Although annual reports were published, they do not contain total budget data. Data are presented in the reports.

The Los Alamos National Laboratory has not provided productivity data. Similarly, the New Mexico Solar Energy Institute, which is part of New Mexico State University in Las Cruces, has not produced a useful annual report.

The Oak Ridge National Laboratory has presented its data in the ORNL Indicators, 1987, which also contains data for selected other national laboratories. It should be noted that productivity data for most of these organizations is not readily available. Furthermore, the Federal Productivity Resource Center has reported that they do not have similar comparative data. As such, comparative data is presented only for the Institute for Energy Analysis and the Oak Ridge National Laboratory.

The National Academy of Sciences describes three center models in the Science and Technology Centers: Principles and Guidelines (Washington, DC: 1987). These are centers organized around a common theme, centers organized around a common facility, and "centers without walls," which primarily function as networking centers.

Figures 14 and 15 compare the publication output per Ph.D. of the Institute for Energy Analysis (IEA) with that of the CEER. The IEA, which had approximately twice the staff of the CEER and maintained in-house facilities and equipment, is a good match for comparison. The IEA had a strong policy emphasis and employed numerous part-time and adjunct staff, as well as hosting several visiting scholars. It maintained two offices, one in Oak Ridge and another in Washington, DC. The IEA also published various in-house reports, contractor reports, articles, papers, proceedings, etc. The publication output per staff Ph.D. by the two organizations is shown in Figures 14 and 15.

"Varied, but the differences are not great. However, IEA had no base funding. Its first director, who later became a distinguished senior fellow, is a renowned scientist with extensive management experience (retired director, ORNL) and ties with Dor. As energy funding declined, they tried to shift their programs to defense issues, a natural transition from their nuclear non-proliferation work. The organization was not successful, and in late 1987 it became a part of the EERC, which absorbed one IEA employee. The following figures are taken from ORNL Indicators, 1987. CEER's "productivity" compares well against ORNL and other national laboratories, even if the figures found in Table 2 are used (Figures 16a, 16b, 16c). It should also be noted that there is a great difference in staff sizes. ORNL's Energy Division is given at more than 165 FTE's in its fiscal year 1985-86 (Figures 17a, 17b). The chi square was not significant for either peer or total at the .05 level. "N" is too small for other, more powerful tests. See ORNL, Energy Division Annual Progress Report for Period Ending September 30, 1986, ORNL-6380, Oak Ridge, June 1987, ch 6.

Figure 14 ON COMPARISON PEER PUBLICATIONS

Figure 15 TOTAL PUBLICATION COMPARISON

Figure 16 by ENERGY DIVISION PUBLICATIONS PER FTE, Source: ORNL, Science indicators page 129.

Figure 17 ENVIRONMENTAL SCIENCES DIVISION PUBLICATIONS PER FTE, Source: ORNL, Science Indicators page 130.

These figures demonstrate the general downtrend in energy funding. This is for..."

Fossil programs, while CEER’s program is primarily in the renewable area, have experienced significant funding decreases. (Fig. 17a) (Fig. 17b) It is possible to compare CEER’s output with other UPR units. However, it must be remembered that the missions and goals of CEER are different from those of academic departments at UPR or any other university. Priorities and outputs differ accordingly.

The EPSCoR Committee undertook a comparative study of the College of Natural Sciences at Rio Piedras, CEER, and the Colleges of Arts and Sciences and Engineering at Mayaguez. The study's report, "Profiles of Graduate and Research Institutions Participating in the EPSCoR Program" notes that data were collected in somewhat different fashions by submitting units, and possibly by subunits. The report begins with a disclaimer about data accuracy.

There are significant differences between the data presented in the EPSCoR report and in this report for CEER. Figure 18 presents an example of these differences. (Fig. 19) The top line in Figure 18 represents total CEER publications per year, while the line beginning in 1980-81 represents total peer-reviewed articles per year, according to CEER. The remaining line is taken from the unnumbered table on page 36 of the EPSCoR report.

Despite attempts to base the analysis in this section on a larger number of documents, efforts to gain access to the necessary data were unsuccessful. Letters and telephone calls went unanswered and publications were missing from libraries.

Total DOE funding (Operating Budget) in millions of 1846 dollars is represented in the following chart.

DOE funding for fossil energy (Operating Budget) in millions is represented in the following chart.

In the EPSCoR document, it is assumed that their lines reflect peer-reviewed articles only. It is assumed that articles listed "in press" are not counted in subsequent years, and hence are not counted more than once in the EPSCoR data set. If this is indeed not the case, the EPSCoR values are inflated.

The method by which publications are counted in the EPSCoR document is unclear. Depending on the methodology, the potential for multiple counting of a single article having multiple authors is possible. However, this probably did not occur, and it is so assumed.

The data for CEER are not subject to this, each paper is counted once (Fig. 19). In Figure 19, the assumption can be made that peer-reviewed articles and reports should carry equivalent weight. It is likewise assumed that both of these are included in the data provided for the Colleges of Natural Sciences, Rio Piedras, and Arts and Sciences and Engineering, Mayaguez by EPSCoR.

It can be argued that Ph.D. scientists conceive of and supervise unit research, and that comparisons should be weighted in that direction. The problem, of course, is that an attempt is being made here to measure units with different missions. Note that the faculty size is a constant for each College because the EPSCoR document reports only three average figures for the period under study: Natural Sciences 61, Arts and Sciences 81, and Engineering 56. CEER is credited with 31. At no time since 1979 has CEER had more than 25 Ph.D. scientists.

However, there are grounds to challenge this assumption. We were able to acquire but one document listing publications by UPR faculty: Synopsis of the Annual Report of the College of Natural Sciences, UPR-Rio Piedras, 1983-1984. Of the 115 listed, a quick count by the author indicates that 8 are proceedings and 40 are "in press." It is not known how these 40 are treated in subsequent listings. Parenthetically, some 70 have two or more authors.

Figure 19

Figure 3. In the preparation of these figures, the actual number of CEER employees reported in the Annual Reports was used, rather than "31." The assumption can be made that peer-reviewed papers and reports are not equal, and should not be treated as such. It is also a challenging assumption that peer-reviewed papers are the most important measure of research productivity for both academic departments and research centers. Figure 20 provides per capita data for all scientists, and Figure 21 is for Ph.D.'s only. The data in Figure 20 includes the number of graduate students in various departments, who probably fulfill many of the same roles as UPR MS personnel (many of whom are graduate students) and are recognized as contributors to the research process (Figure 20). By these comparisons, CEER has had higher per capita production than the other three UPR units if both peer review and report publications are considered. The comparison is slightly less favorable if only peer review articles are considered. If any of the three identified possible errors in the EPSCoR data occurred, CEER compares even more favorably. See EPSCoR, "Profiles..." p. 14. Note: The EPSCoR Report only provides an average faculty size for the five-year data set, thus only three figures. It does, however, provide a table of the numbers of graduate students per unit per year. The average faculty figure and the reported actual number of students were used in the analysis. If faculty size increased over the years, per capita publications are exaggerated for UPR faculty. For example, the document reports a faculty size of 61 for the College of Natural Sciences. An inquiry to the College puts the faculty size at 114 for the School year 1987/88. Despite numerous attempts, we have been unable to locate a source for faculty size over time. Therefore, there are at least three possible ways the EPSCoR data are inflated for the Colleges.

Figure 41 shows data for the year 1963-80.

Section 1. CEER Productivity has increased since FY 1979/80. This increase in productivity was maintained even as the transition from DOF to UPR base funding began. The increase in productivity can be measured in several ways. These include a successful transition during a challenging funding period and maintaining organizational integrity as programmatic areas changed. CEER has demonstrated flexibility in that it has found new clients and has evolved new programs, both in research and service, to focus on issues and problems in Puerto Rico and the region. It also continues to serve old clients in new ways.

Section 2. CEER Productivity appears to compare favorably with other research organizations as well as with the College of Natural Science at Rio Piedras and with the Colleges of Arts and Sciences and of Engineering at Mayagüez. The data on hand are too uncertain and existing methodologies too inadequate for further certainty. Moreover, it is precarious to make the comparison, at least with academic units.

Section 3. CEER has successfully weathered a challenging funding period. Competitive funding is increasing in real terms as well as a percent of the total budget. The fact that CEER has maintained its institutional integrity can be attributed to CEER having a stable funding base from UPR. It needs to maintain this funding base if it is to continue to be successful. It should also be noted that...

CEER's productivity in recent years has been greater than in the 1970s, despite the fact that institutional funds are currently half the level they were in the 1970s, in real terms. Furthermore, CEER's productivity needs to be assessed not only in terms of publications, but also in service. Its service functions have expanded and are likely to continue to expand. These include not only energy conservation programs for the University, but also educational functions (SssP), as well as the promotion of research in the University and the Island. In conclusion, those factors that can be measured according to the SRI International guidelines have improved over time. Its publications are increasing per capita, and the publication rate is not out of line with similar organizations; nor, for that matter, with academic departments at the University of Puerto Rico.