

EVALUATION OF CEER PRODUCTIVITY
1979-80 TO 1987-88

Wallace C. Koehler, Jr.
June 1988



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Introduction

In recent years much concern over productivity has been expressed in many circles: 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 that they are necessary both for purposes of organizational control and for 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...."¹

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 mission and goals, shifts in 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 attempt is made to provide one. Each evaluator may provide whatever weight s/he

¹Senior Advisory Committee, Report to the University of Puerto Rico President, August 20, 1987, p. 6.

deems appropriate to each of the factors which make up "performance" or "productivity" assessments.

On Productivity

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. Typically, publications are usually disaggregated as peer reviewed, symposium proceedings and conference papers, and sometimes reports. Peer review 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.² In any case, the importance of patents depends on disciplines and sub-

²Personal communication, Sandor Boyson, April 1988. The survey results are not as yet final.

disciplines. Some fields, by their very nature, are likely to result in more patentable work than 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 model: 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."³ 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.

³Sink, D. Scott, Thomas C. Tuttle, and Sandra J. DeVries, "Productivity Measurement and Evaluation: What is Available?" *National Productivity Review*, 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: human beings' effective response/reaction to working and living in organizational systems.

6. Innovation: the creative process of adaptation of product, service, process, structure, etc., in response to internal as well as external pressures, demands, changes, needs, etc.

7. Profitability/budgetability: a measure or set of measures that assess attributes of financial resource utilization.⁴

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.⁵

This is a purposefully ambiguous definition and encompasses several of the factors defined by VPI. But it can be a useful guide if appropriate definitions are adopted.

⁴Ibid, pp. 267-8. 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.

⁵Executive 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, in effect to define "efficiency," "service," "product," "quality," and "timeliness."⁶

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 yet extended these guidelines to federal GOGO (government owned, government operated) or GOCO (government owned, contractor operated) laboratories.⁷ Enquiries to two DOE GOCO laboratories establish 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.⁸ Oak Ridge National Laboratory does collect data on itself and selected other laboratories. These data are published periodically to assist management in making assessments. Data from ORNL Indicators, 1987, the latest set, are presented below.

DoD GOGO laboratories have attempted to quantify productivity, but these methodologies have come under criticism both

⁶Office of Management and Budget, Bulletin No. 86-8, February 28, 1986.

⁷Telephone interview, Federal Productivity Resource Center, March 1988.

⁸Telephone interviews with Ronald Lohrding, Los Alamos National Laboratory, and Thomas Wilbanks and Beverly Wilkes, Oak Ridge National Laboratory, March 1988.

internally⁹ and externally.¹⁰ The National Institutes of Health have utilized bibliometrics¹¹ to track the "quality" of work resulting from their grants and as a tool for grant making decisions (more on methodologies follows). It is interesting to note that the National Science Foundation, in its biennial Science Indicators,¹² 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.¹³

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," SRI International¹⁴ and the Institute for Energy Analysis¹⁵ acknowledge that productivity assessment is desirable, but both indicate that they know of no quantifiable method to do so.

⁹Cpt. Thomas A Fauth, USAF, "Productivity Measurement in Research and Development Laboratories," MS Thesis, Air Force Institute of Technology, Air University, September 1981.

¹⁰Alfred H. Schainblatt, "Measuring Productivity of Scientists and Engineers in R&D: A State of the Practice Review," Final Report, The Urban Institute, Washington, DC, May 1981.

¹¹A definitive description of bibliometrics can be found in Research Funding as an Investment: Can We Measure the Returns?-- A Technical Memorandum (Washington, DC: US Congress Office of Technology Assessment, OTA-TM-SET-36, April 1986), chapter 3.

¹²National Science Board, National Science Foundation, Science Indicators, 1985. The 1987 report is in draft.

¹³Office of Technology Assessment, *op cit*, p. 4.

¹⁴Richard Marciano, Vice President, SRI International, March 1988.

¹⁵Jack Barkenbus, March 1988, now with the Energy, Environment and Resource Center, University of Tennessee, Knoxville.

There is an impressive literature on methodologies used by industry to measure R&D productivity. A "state-of-the-practice review" of these methodologies concludes:

There are no currently used systems for measuring the productivity of scientific and engineering groups without **substantial flaws** [emphasis added]. Nor does the literature on productivity measurement offer encouragement that suitable systems will soon be available.¹⁶

Universities too are concerned with R&D productivity. The classic approach has been to count the number of articles researchers produce, that is to say "publish or perish." Flaws with this methodology have long been recognized: different disciplines publish in different styles; having a publication is not an indicator of the quality of the publication; likewise, it is no indicator of the impact of the "knowledge product" on the progress of science. Citation counts, the number of times a research product is cited by others (and by self) in subsequent research products, were an early first attempt to assess the impact of published research. Narin, one of the recognized experts in bibliometrics, contends that the first such attempt was in 1917, and that the work by F. J. Cole and B. Beales in *Science Progress* remains relevant today.¹⁷ However citation counting has its limits. By the mid-1960s, researchers sought a means to depersonalize the evaluation process. The advent of iSi's Science Citation Index, and the subsequent Social Science Citation Index provided data bases which can be analyzed through

¹⁶Alfred H. Schainblatt, "How Companies Measure the Productivity of Engineers and Scientists" *Research Management*, 2, 7 (May 1982), p. 10. Also Richard Pappas and Donald Remer, "Measuring R&D Productivity" *Research Management*, 5, 7 (May 1985). Michael B. Packer, "Analyzing Productivity in R&D Organizations," *Research Management* 3, 1, (Jan-Feb. 1983) suggests "output mapping" as a tool for subjective assessments.

¹⁷Francis Narin, "Bibliometric Techniques in the Evaluation of Research Programs," *Science and Public Policy*, 14, 2 (April 1987), pp. 99-100.

computer aided methodologies. The indices permit counts of publications, citations, researchers, and their location. Coauthorships could be managed.¹⁸

Bibliometrics was developed to assess and map the sources of the significant contributions to the scientific process. It concerns itself with where articles are published and with which journals are most frequently cited. The fundamental assumption is that those journals which are most frequently cited are the most influential journals in any field or sub-field [this assumption contains at least the seeds of tautology]. Since citations are retrospective, that is, they measure work which was performed in the past, and which was 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 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, a priori, publishing the most influential work. Bibliometricians are quick to stress, however, that these comparisons must be made only among units in the same fields, performing similar functions. Indeed, these comparisons should perhaps be limited to sub-fields, because the publications 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 and papers, and theses. As no bibliometric track record exists against which to assess the probable impact

¹⁸Office of Technology Assessment, *op cit.*

of a new publication, these "knowledge products" do not "count."¹⁹

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.²⁰ Again, because of their nature, applied research centers will not score so well on bibliometric scales because their "knowledge products" are sometimes proprietary. Or 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, further, are less likely to produce

¹⁹Francis Narin, President, CHI Research/Computer Horizons, Inc., telephone interview, March 1988, concedes that reports are impossible to handle with the methodology, for no quality stratification is possible. While books could be stratified, it is extremely difficult to do. He therefore does not attempt to measure either.

²⁰A. Anderson, "Research Gradings Stir Emotions," *Nature*, 322 (July 24, 1986). OTA, *op cit*, p. 40. Cf Narin, *op cit*, p 100.

peer reviewed publications, as well as total "knowledge products," again because of the nature of the effort.²¹

Carpenter et al caution further, that bibliometric techniques probably do not produce statistically significant results for units producing less than thirty publications per year per field or sub-field.²² With the possible exception of the Department of Physics at UPR, Río 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 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]."²³

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 insure that the index numbers were generated in exactly the same fashion, using the same assumptions, and that those assumption are explicitly stated. If the units being compared are

²¹Stuart Nagel, *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, Approaches to Appropriate Evaluation: A Report on a Series of Workshops on Evaluation*, (Washington, DC, 1978).

²²M Carpenter, F Gibb, M Harris, J Irvine, B Martin, and F Narin, "Bibliometric Profiles for British Institutions: An Experiment to Develop Research Output Indicators," *Scientometrics*, in press.

²³OTA. op cit, p 40, quote at p 36.

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 Committee (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 nor 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.²⁴

²⁴Personal communication, Richard Marciano, March 1988. Marciano argues that for "research product numbers," it is important to remember that "...qualitative drives quantitative

CEER Productivity

Given the preceding, it is with both temerity and trepidation that the following discussion of CEER productivity is presented.

CEER performs both basic and applied research as well as engineering. It is a service organization as well as a user facility. CEER's mission is four fold:

To serve as the focus for energy and environmental research and development for Puerto Rico.

To develop for the United States and Puerto Rico economically competitive alternative energy technologies that are socially and environmentally acceptable.

To conduct tropical ecological research for the sound management of resources.

To serve as focus for technology transfers in energy and environmental matters for the Caribbean region.

CEER research and service focuses directly on Puerto Rico and the region. Contract research currently underway, for example the municipal waste program (PRMWA), the Aguirre biomass project (PROE), and the water rate survey (PRASA), all address pressing problems of the Island. Research supported internally often has the same focus. Examples are the residential energy use survey as well as the industrial R&D survey, being conducted for the Governor's Adjunct Council on Science and Technology in coordination with the Planning Board and the Economic Development Administration (Fomento). Data from both surveys have been used by ELA government agencies in the policy process. The basic research conducted at CEER, likewise, is research into the character of Puerto Rico and the region.

over time."

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, one must take care in evaluating and/or comparing one type of output as 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 of CEER, as it undergoes the transition from a DOE GOCO laboratory to a service and research institution of the University of Puerto Rico. Finally, the funding environment may change, thereby impacting and changing programs. CEER has undergone a significant redefinition of its energy programs because of changes in federal policy. DOE's policy on renewable and international programs has turned from enthusiasm to apathy. Several programs at CEER have had to be eliminated or reduced, notably OTEC and solar energy. At the same time, 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, as well as in social science survey research. The biomass program has been reborn. At the same time, established programs such as marine and terrestrial ecology continue. Changing research agendas require time and retooling. Necessarily, one must expect reductions in "research products" during periods of transition. Publications cannot be generated from programs under-going start-up. The demands of start-up, in turn, reduce the time available to scientists to wind down and appropriately mine "old" research; as does the necessary process of the writing of new grants to fund new projects.

Fourth, CEER is both a service and research organization. Begun 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.²⁵ 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 is the product of a CEER initiative, and CEER continues to provide administrative services to the Center. It seeks to support university research in response to the needs of industry. It was originally conceived in September 1983 and was formally established in January 1987. To date the Center has made six research grants to faculty of Island universities, focusing on areas of interest to the chemical and pharmaceutical industries.

Most recently, CEER received a grant from DOE, under its Minority Educational Institution Assistance Program to facilitate energy research at UPR. The program entitled 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 qua research for CEER. Nor will they generate any "research measures" for CEER. Both may, however, 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

²⁵It is recognized that a science and technology educated populace is important 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. See 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, 1988, p. 4.

fellowship program. 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 rain forest are housed, and use CEER laboratories. Over the past five years, the average number of non-CEER researcher days by faculty and students at El Verde have been 172 and 268, respectively. Research at El Verde has resulted in at least 45 peer review publications over the same period, for many of which CEER receives no "credit".

CEER personnel consult with government and the private sector, serve on boards, teach classes at UPR, perform research and other services often on a pro bono basis. The results of these activities may not be "research products," but are a clear service to the community. Those programs, like ISADER, which are funded, may, in fact, depress CEER's "research indicators." For example, they increase the CEER budget, thereby reducing the apparent output of "research products" per dollar. Those services provided pro bono by scientists require time, time that might be spent doing other things. That too 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 winds down, another begins, sometimes with gaps. OTEC devolved, the Integrated Energy Dairy Farm project emerged. The work at Juana Diaz was completed. How many published "research products" from Juana Diaz resulted? A search in several data bases through Dialog for 1986 found none, while the Energy Research Abstracts Index for the same year shows three. Today, 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.

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, (3) manpower availability.

Physical Resources

Since 1979 there have been major changes in physical resources available to CEER scientists. Río Piedras and Mayagüez staffs have fluctuated in size, and that has resulted in some strains on staff office facilities at Río Piedras. Laboratory space has been converted, for example, to house the Industry/University

Center and the small conference room has been converted to office space. The research site at Cornelia was closed down.

The major change in equipment is the proliferation of micro-computers. That, 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 to research functions. An increasing proportion of non-discretionary monies are assigned to service, as is shown below (Figure 6).

Since FY 1979-80, CEER's funding has shifted, and has been at times uncertain. As is 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.

(Fig. 1a) (Fig. 1b)

Not only has the budget undergone change, the sources of funding have also changed significantly.

(Fig. 2)

As Figures 1a and 1b show, not only did the source of institutional base funding shift entirely from DOE to UPR, that UPR institutional funds are approximately half 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. Because of institutional

Figure 1(a)

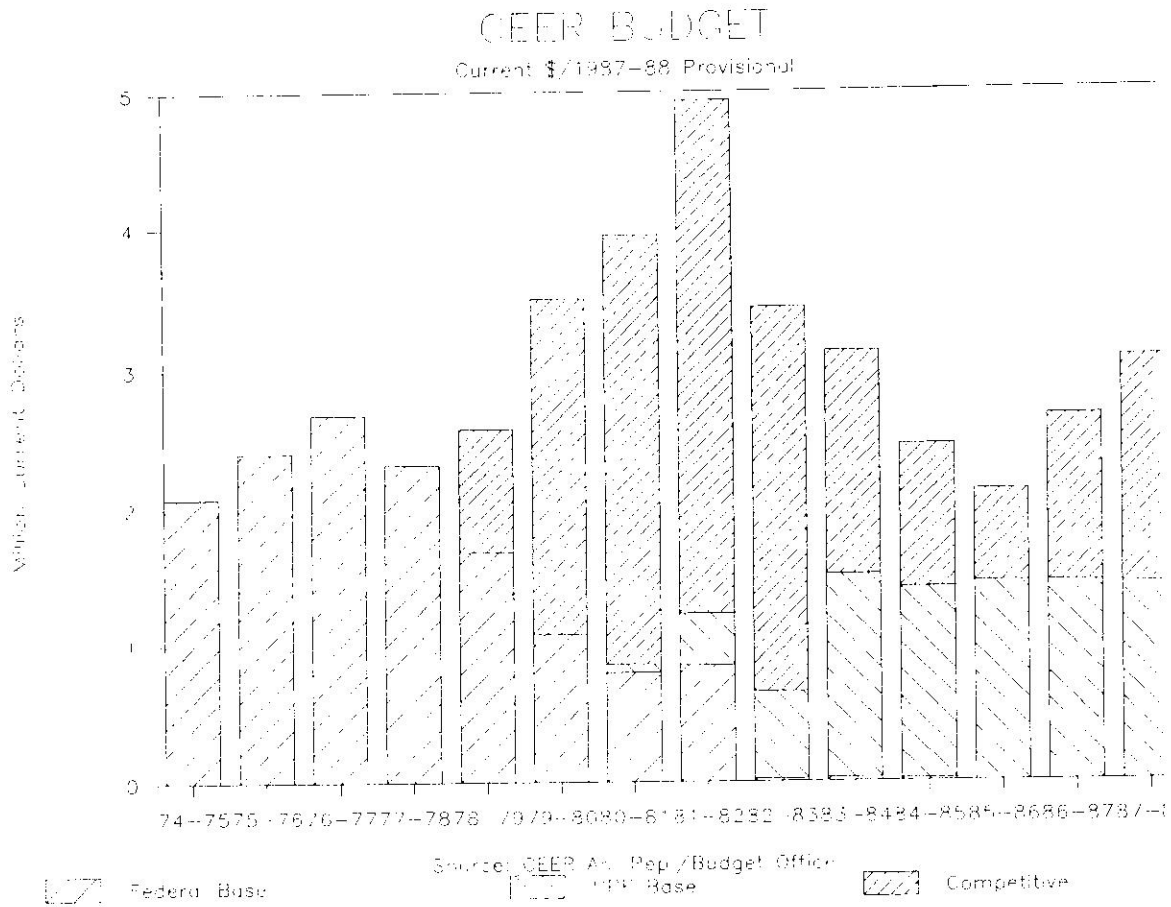


Figure 1(b)

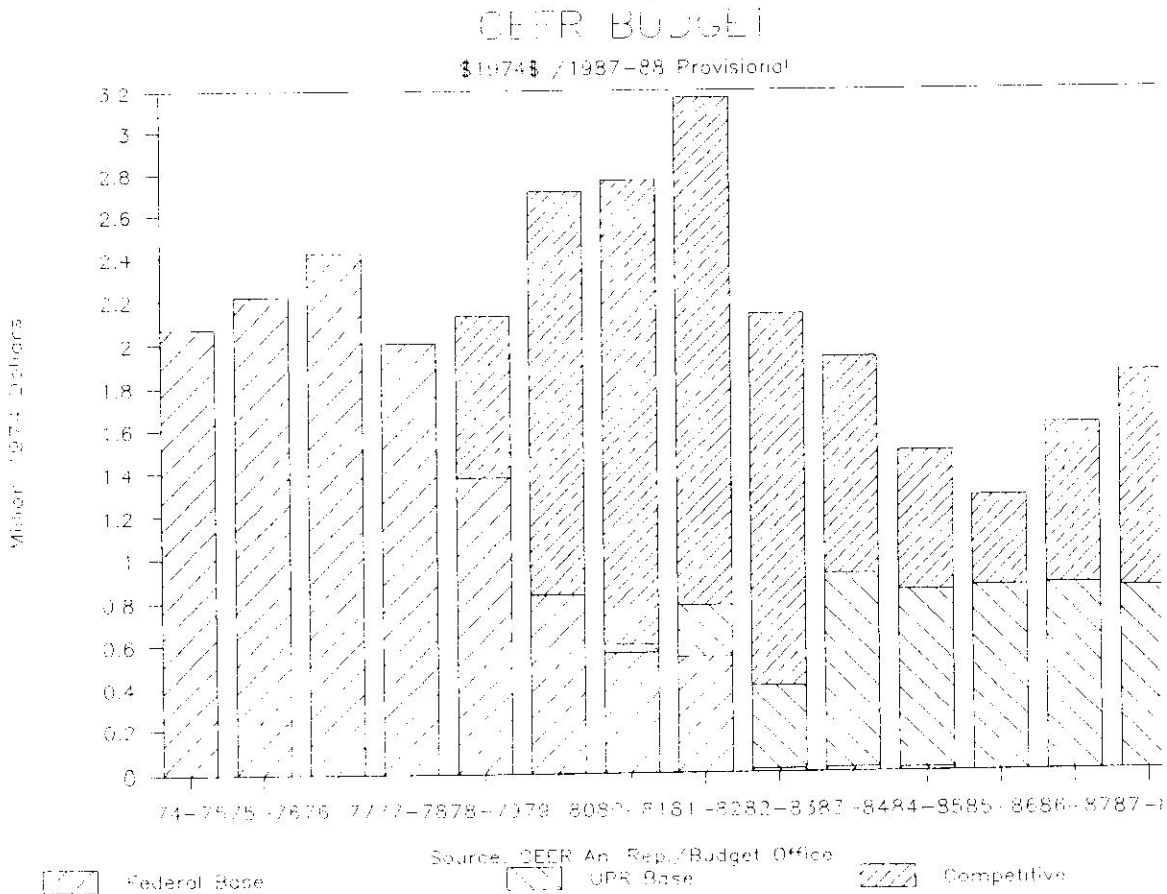
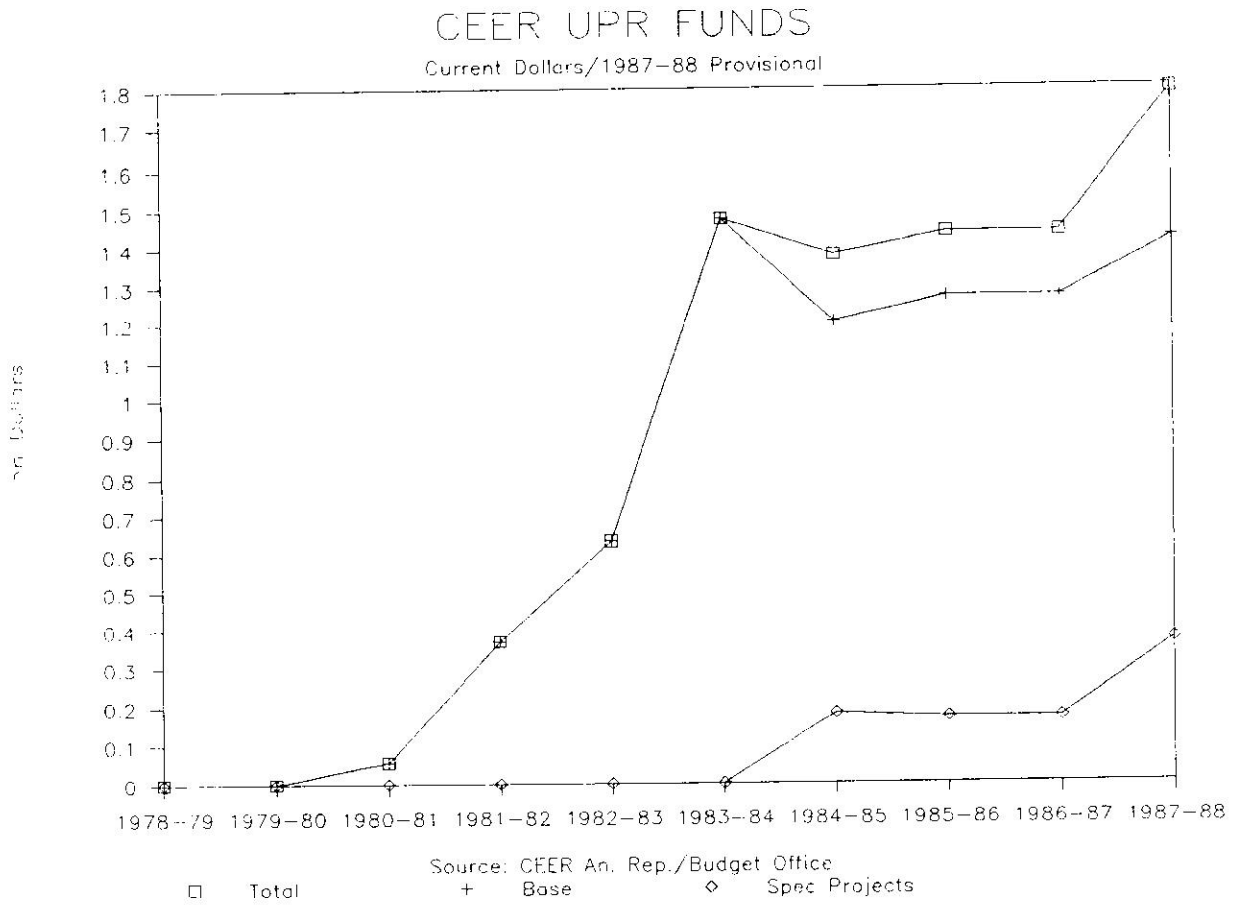


Figure 2



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 deemphasis of the Reagan Administration 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. Bear in mind that no CEER research is funded by these monies.

CEER has historically -- as its name implies -- 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 the three cases, federal funding has begun to increase. With the exception of Energy, ELA funding has declined. Again, 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. CEER dependence on UPR funds for its research and service programs has declined in relative terms in the last three fiscal years. But it also underscores the need for base funding to an organization such as CEER to weather changing funding tides, and to overcome those changes in order to redirect its research and service programs in an efficient manner. Without UPR base funding, an organization the size of CEER, with a dedicated mission, would founder in an uncertain or changing environment.

Personnel

It approaches redundancy 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 have administrative responsibilities only are not included in the data set here 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. 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 the author to substantiate the conclusion, the number of "FTE" consultants²⁶ is probably down.

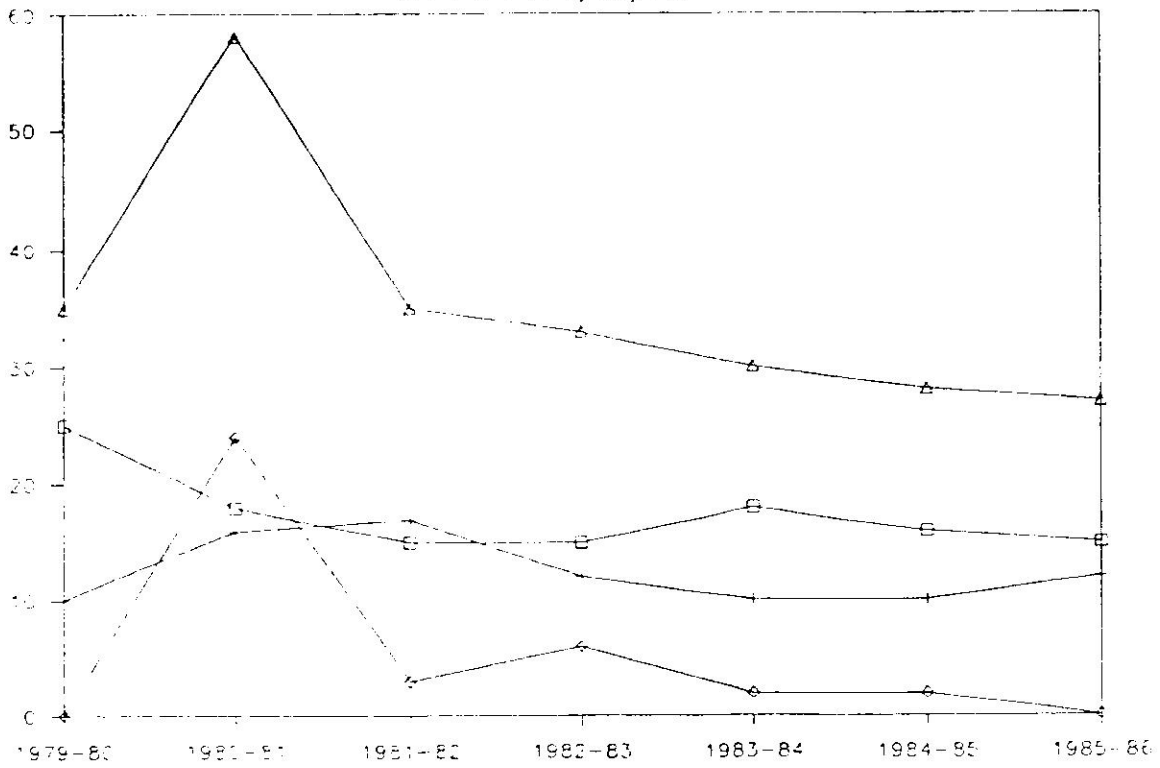
While there has been relative stability of employee numbers, their distribution among programs have varied significantly, particularly in the energy division. The relative stability in funding for the environmental group is reflected in the relative stability of the personnel count. Funding instability and new energy programs have led to significant variations in personnel assignment. It should be noted that these changes do not necessarily represent new hires or fires, much is staff "changing hats."

(Fig. 3) (Fig. 4)

²⁶The term "consultant" is administrative. Several categories of association are implied: adjunct scientist, part-time scientist, as well as part-time administrator. See page 23 for a more extensive definition.

Figure 3

CEEP AND CENR
Scientific Staff by Degrees



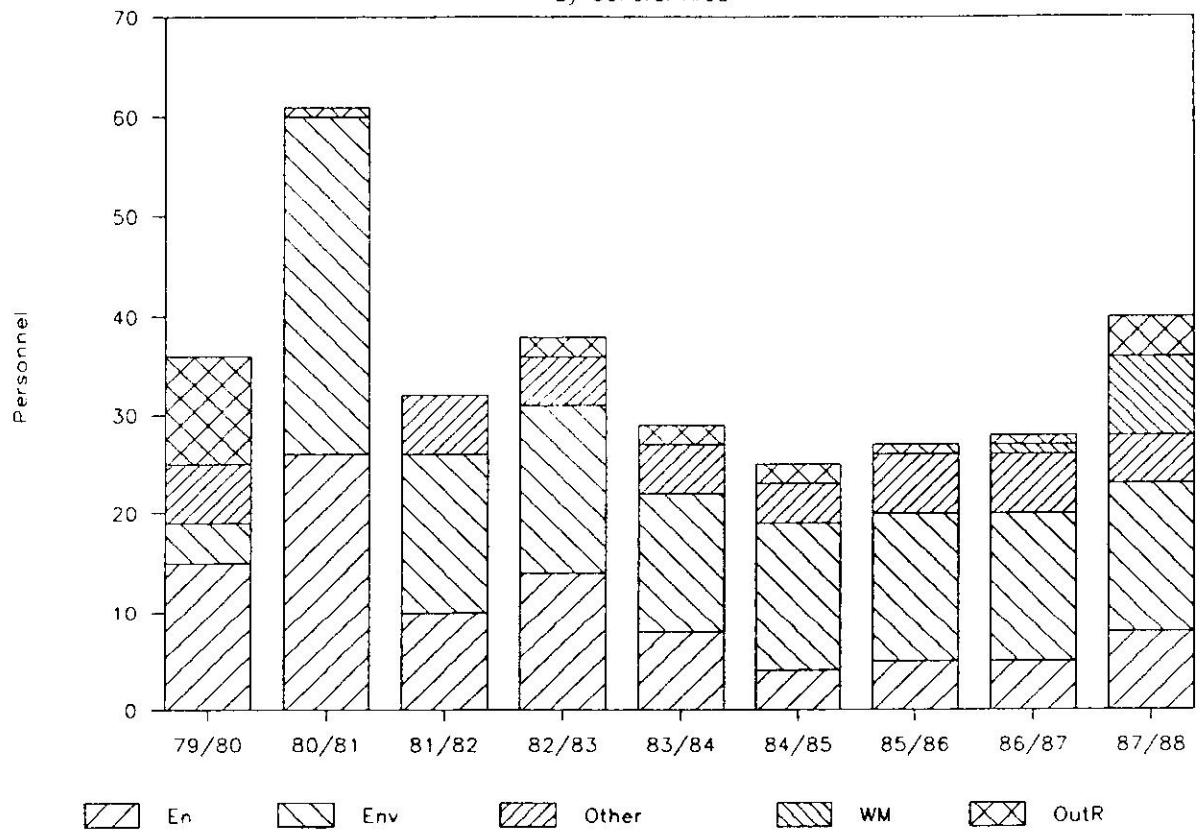
Source CEEP Annual Reports

□ Ph.D. + M.S./M.A./M.F.A. x BS/BL △ TOTAL

Figure 4

CEER PROFESSIONAL STAFF

By General Area



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.

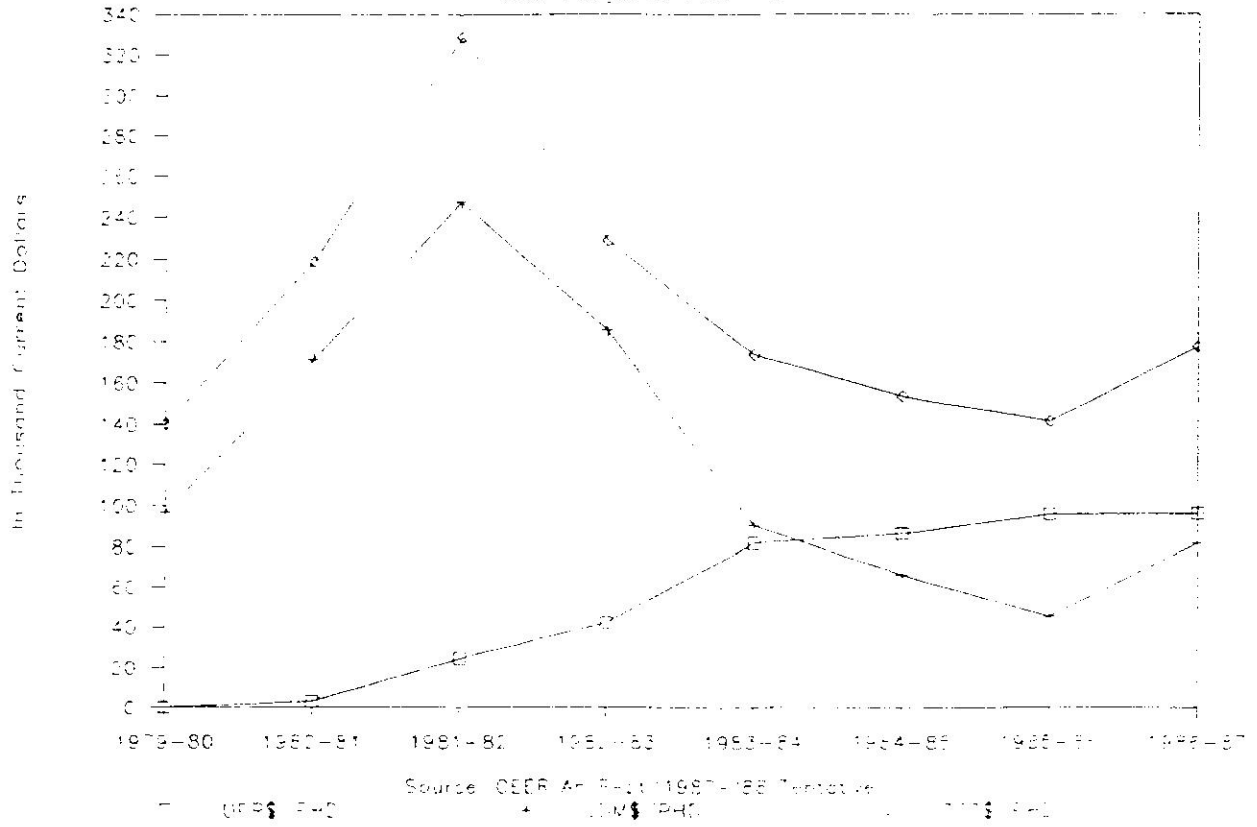
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Again, extreme care must taken when comparing inter-organizational data. The numbers can vary greatly according to

Figure 5

CEER FUNDS PER PHC

Total Budget by Total PHC



calculation assumptions. By way of example, compare Tables 1 and 3. Both appear to measure the same thing: the number of CEER publications. Table 1 does not. Table 3 does, but Table 1 only counts the total share of publications by CEER associated PH.D.'s. Publications by those at the Master's level and below, including ABD's, are not counted. The same cautions hold when interpreting Tables 2 and 4. Tables 1 and 2 are measures of CEER associated Ph.D. "knowledge product" productivity, under the stated set of assumptions. Tables 3 and 4 measure total CEER "knowledge product" output. Figures 6(a) and 6(b) show in graphic form the difference between the "complex" and "simple" methodologies. Thus two methodologies have been used in the analysis of CEER output. These are termed "complex" and "simple". In the "simple" methodology, total publications, disaggregated by type of publications, as listed in the Annual Reports are reported for each year. In the "complex" methodology, the share each author(s) has in each publication is calculated. This permits 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 has to be employed because of the paucity of data for comparisons between or among organizations.

(Fig. 6a) (Fig. 6b)

Assumptions for PhD Count Only

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

Figure 5 (a)

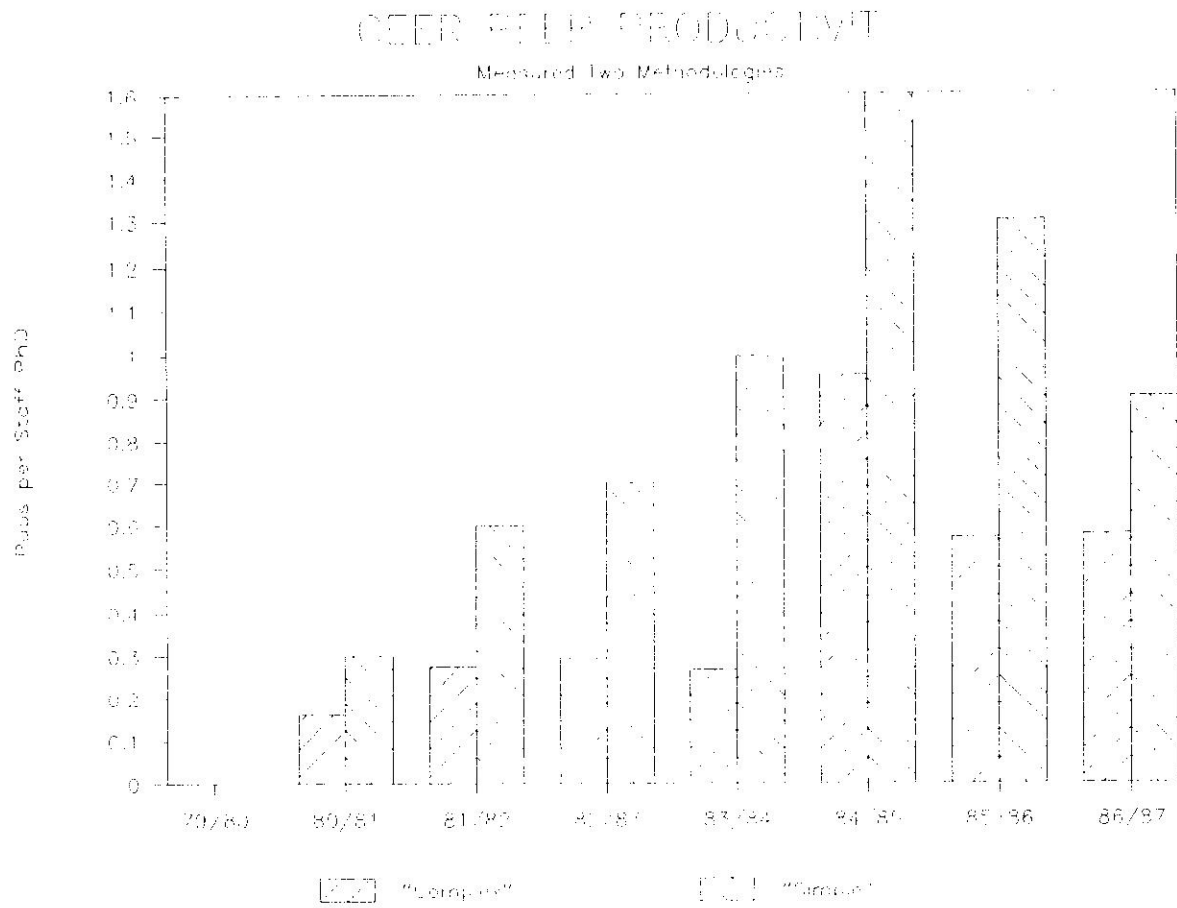
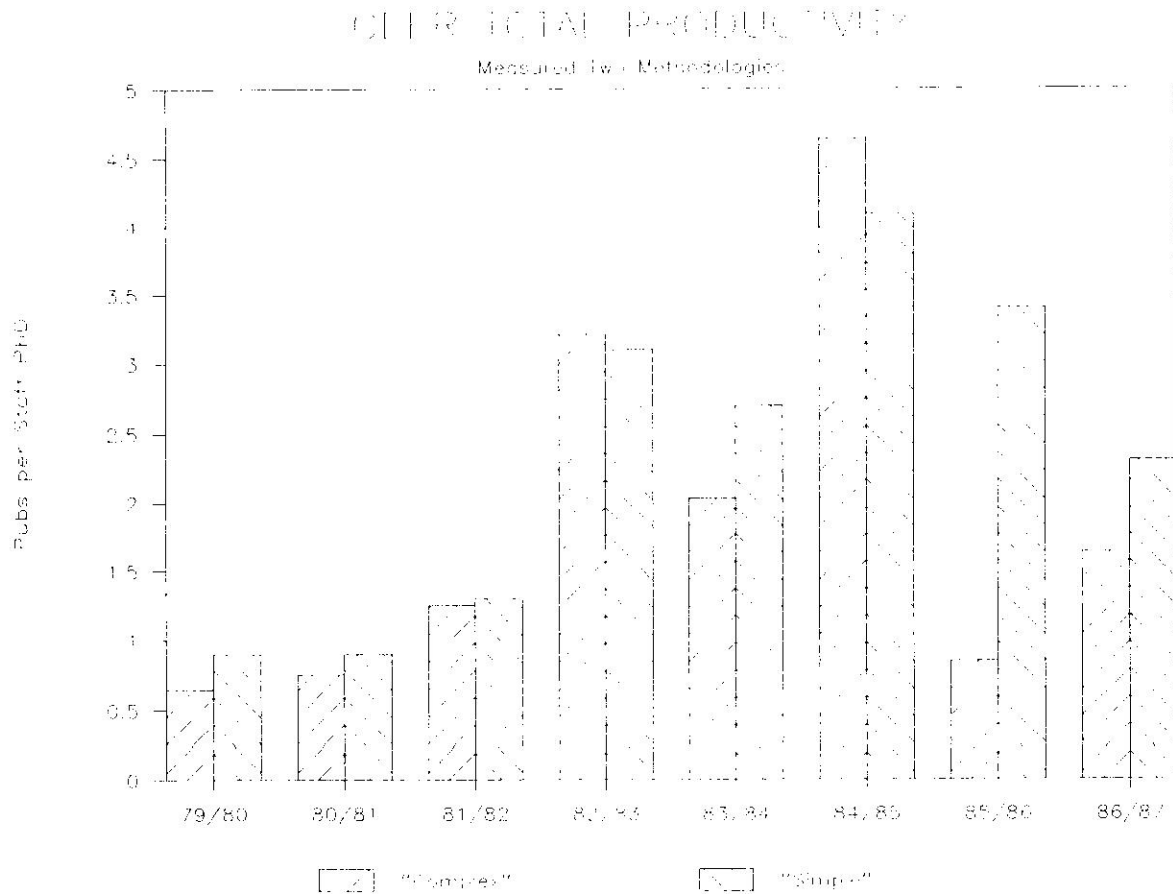


Figure 5 (b)



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; since CEER publications sometimes carry multiple authorship (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 coauthor, you received credit for 0.5 publications, and so on. This permits a careful analysis at the institutional level (and with some adjusting to the division or other level). The institution receives thereby one credit per paper, less those excluded as explained in (3)(a)(i) [see the discussion on "simple versus "complex" methodologies above].

3. CEER has three general categories of "associates."

- (a) (i) Employees and staff. CEER employees PhD's and equivalents ("terminal" professional degrees: MD, MBA, LLB/JD), Masters level, Bachelors level, and Non-degree. All of these are indicated as direct participants in the research process. And a number of MS level scientists have publications to their credit. Academic departments usually do their vitae 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 PhD's divided by the total number of staff PhD's. Excluded is credit for publications by CEER staff at the MS level or below. If MS scientist credit is given, then one must determine whether to include all MS scientists, or only those who publish in subsequent calculations.²⁷

²⁷It 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 colleagues. And thus it was. In any event, the "institutional memory" may be inadequate to handle each case properly.

- (b) Adjunct staff and consultants. CEER has multiple functions, and maintains research and other contacts with a large number of people. They are listed as adjunct or consultants in the Annual Reports. Others perform non-research roles. The publications contributions of adjunct staff were also "fractionalized." Only those adjunct staff who published were considered "research adjunct staff" and included in the denominator (totals and number of research adjunct staff are shown in Table 1).
- (c) Coauthors. While, not included as adjunct staff, numerous persons were credited with CEER publications, peer and otherwise. Most are coauthors with CEER scientists. Their contributions were likewise fractionalized (totals and number of coauthors 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 does one weight one over another? Let us remember that CEER research is often contract research, as opposed to 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 press" or "submitted". In Tables 1 and 2 below, "peer publications" are those articles which are reported in the Annual Reports as published, it excludes from the count those indicated as "in press." The figure for TOTAL includes everything reported, including those "in press."

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

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

YEAR	CEER		ADJUNCT		COAUTHOR	
	PEER	TOTAL	PEER	TOTAL	PEER	TOTAL
79/80	0	15.5	0	0	0	10.7
80/81	2.6	12	0	2	6.5	19.9
81/82	5.5	25.1	0	3.4	0.5	9.8
82/83	4.7	51.4	6.9	21.8	1	7.7
83/84	5.3	40.6	1.8	8.5	2.7	16.6
84/85	15.2	74.2	6.3	20.3	4.2	19.4
85/86	8	11.8	8.5	26.4	11.8	26.4
86/87	8.7	24.5	2.2	5.6	7.7	14.2

Source: CEER Annual Reports

The measure of publication productivity is generally given in per capita terms. Table 2 provides these data for each category of CEER research personnel (CEER PhD's, Adjunct, Coauthors). Again, the most conservative assumptions were made.

(5) 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 CEER ASSOCIATED PHD

<u>FY</u>	<u>PEER</u>	<u>TOTAL</u>
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

(6) As is shown above the past decade was a cyclical one for CEER'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 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 is discussed in the introduction, CEER scientists produce essentially three types of "research products." These are (1) reports, (2) peer review articles/books, and (3) non peer review articles, proceedings, conference presentations. This data set consists of the total number, in absolute terms, of publications, by type, reported in the Annual Reports. Publications with

Figure 1

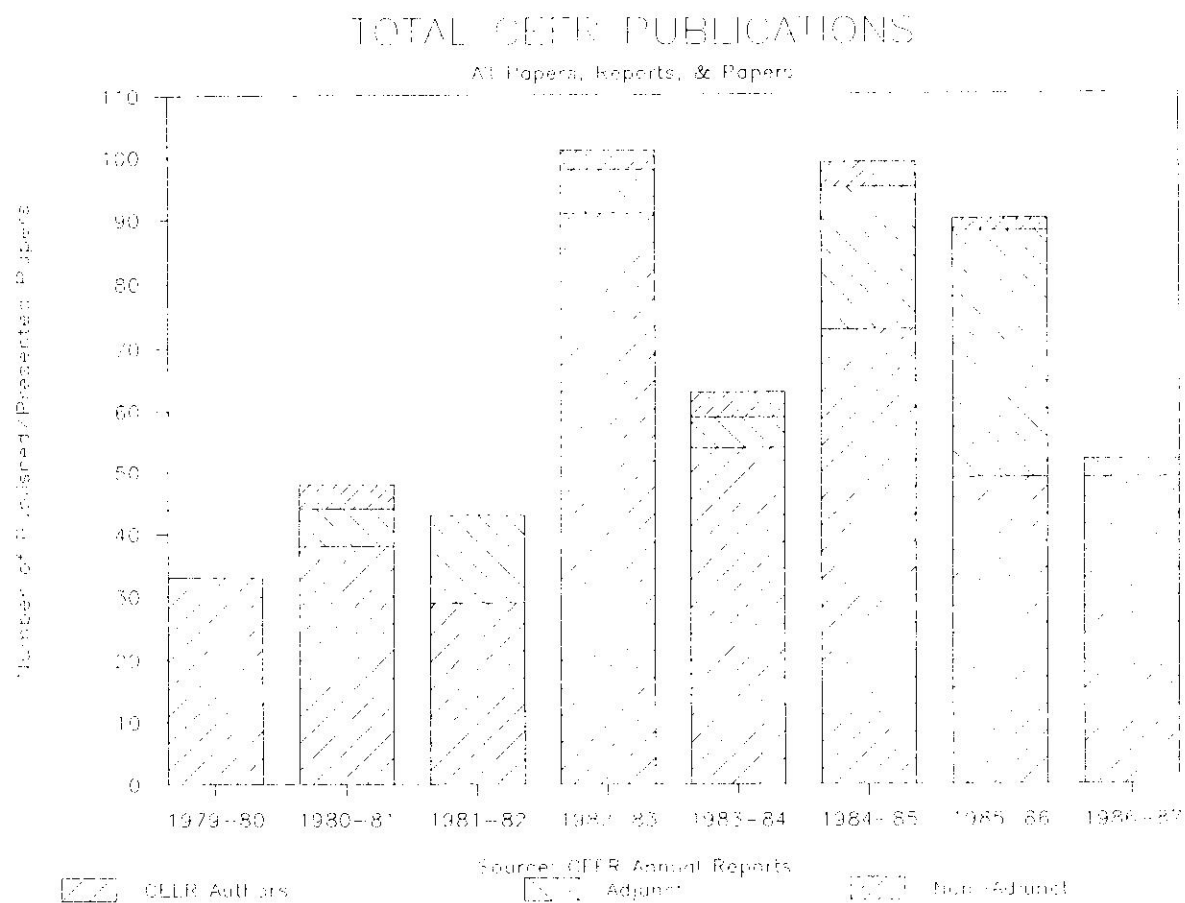
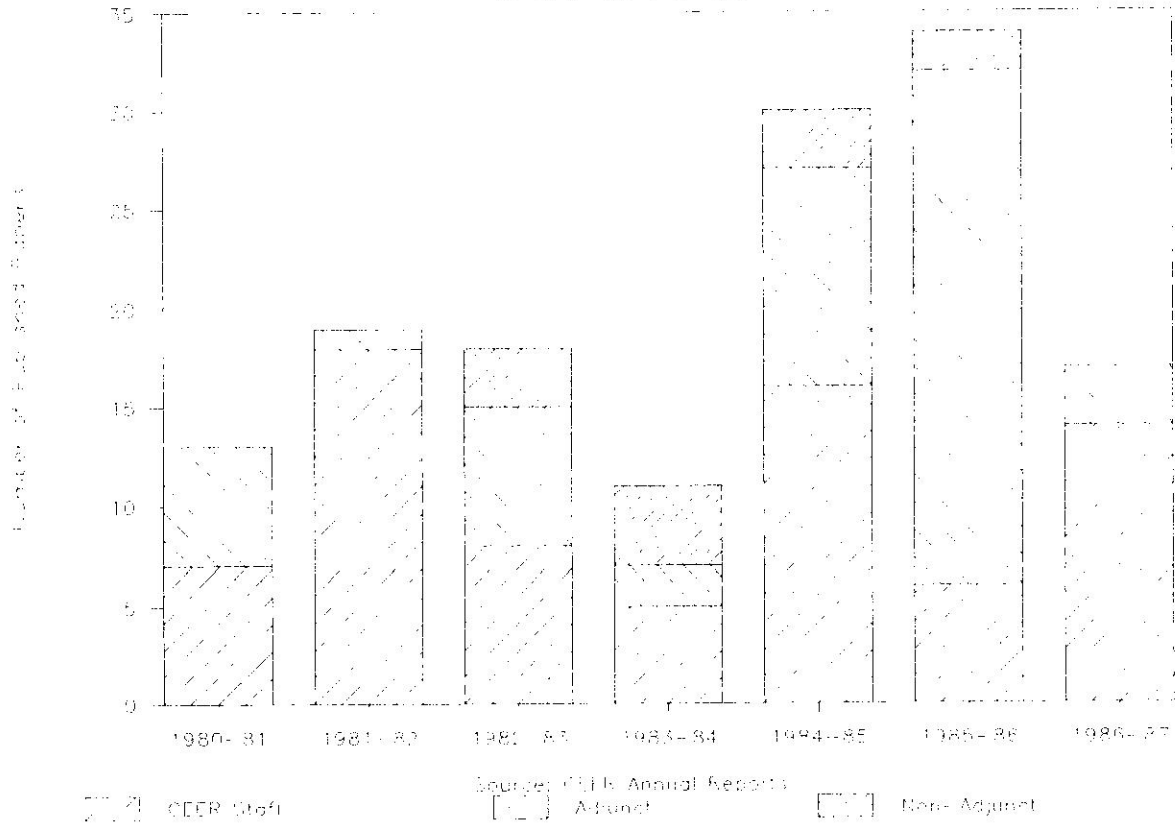


Figure 8

CFER PAPER REVIEW PUBLICATIONS

By Relationship to CERP



multiple authors are counted but once. Creation of this data set is necessary if comparisons of data from other organizations are to be made, and because it is the most common approach. Second, the preceding was an analysis of CEER doctoral level "knowledge product" output, but not of the entity.

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, etc. 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 jump and decline in the number of conference proceedings and papers result from two phenomena: first, the relatively small size of CEER and, second the number of international meetings in San Juan in any given year.²⁸ CEER scientists took advantage of no cost travel to make presentations. Thus the perturbation.

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. 11)

Additional data are provided in Tables 3, 4, and 5.

²⁸For 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 Investigación Científica, Tropical Hydrology Symposium, Inter-American Congress of Chemical Engineers, and the Inaugural Meeting of the American Association for the Advancement of Science, Caribbean Division.

CEER PUBLICATIONS

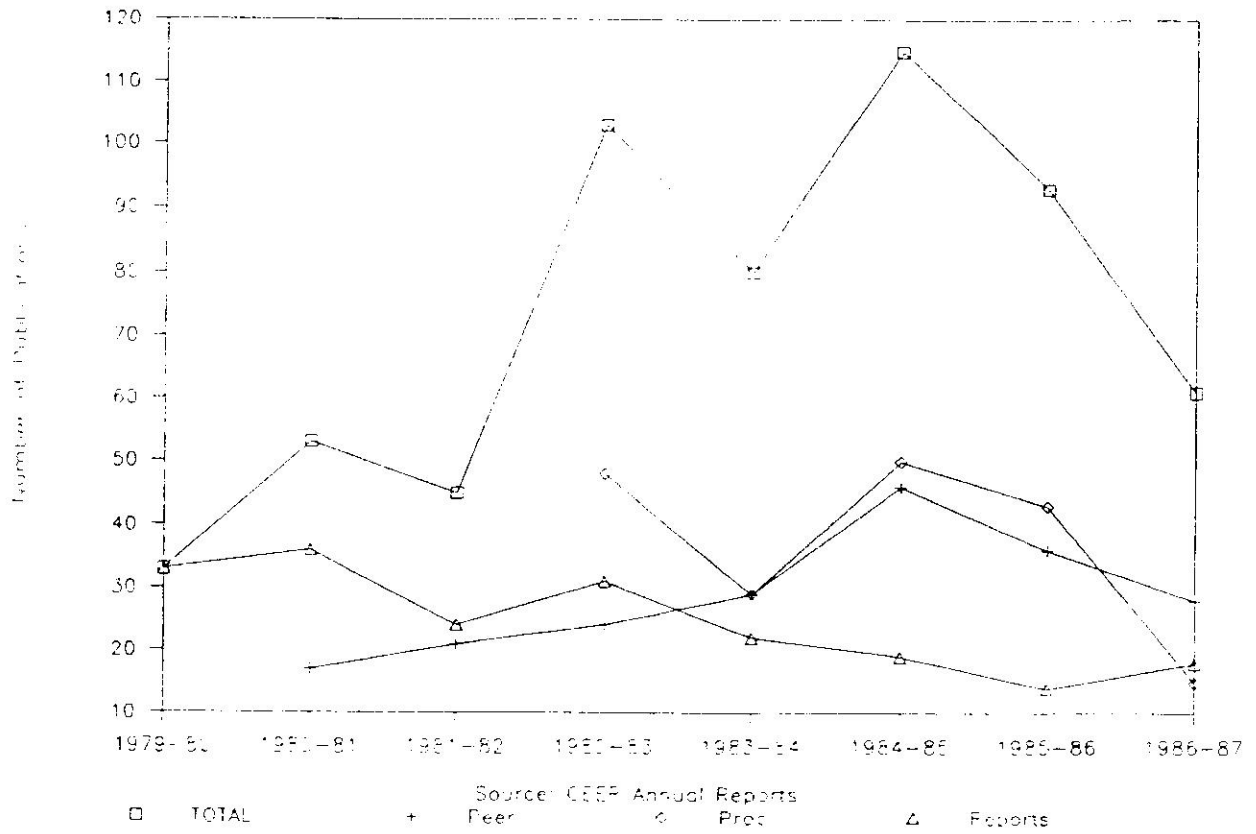


Figure 10
 CEEP PUBLICATIONS

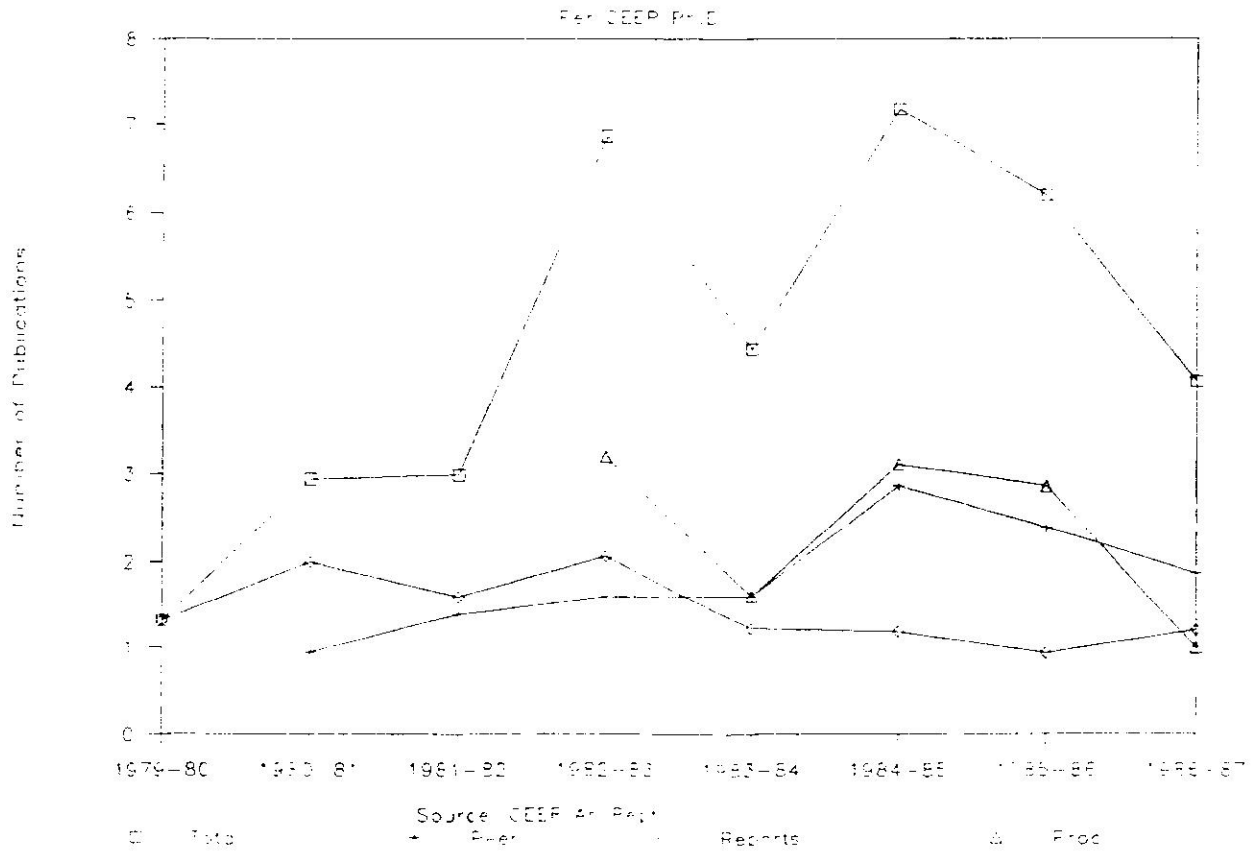


Figure 11

CEEP PUBLICATIONS

Per CEEP Scientific Staff

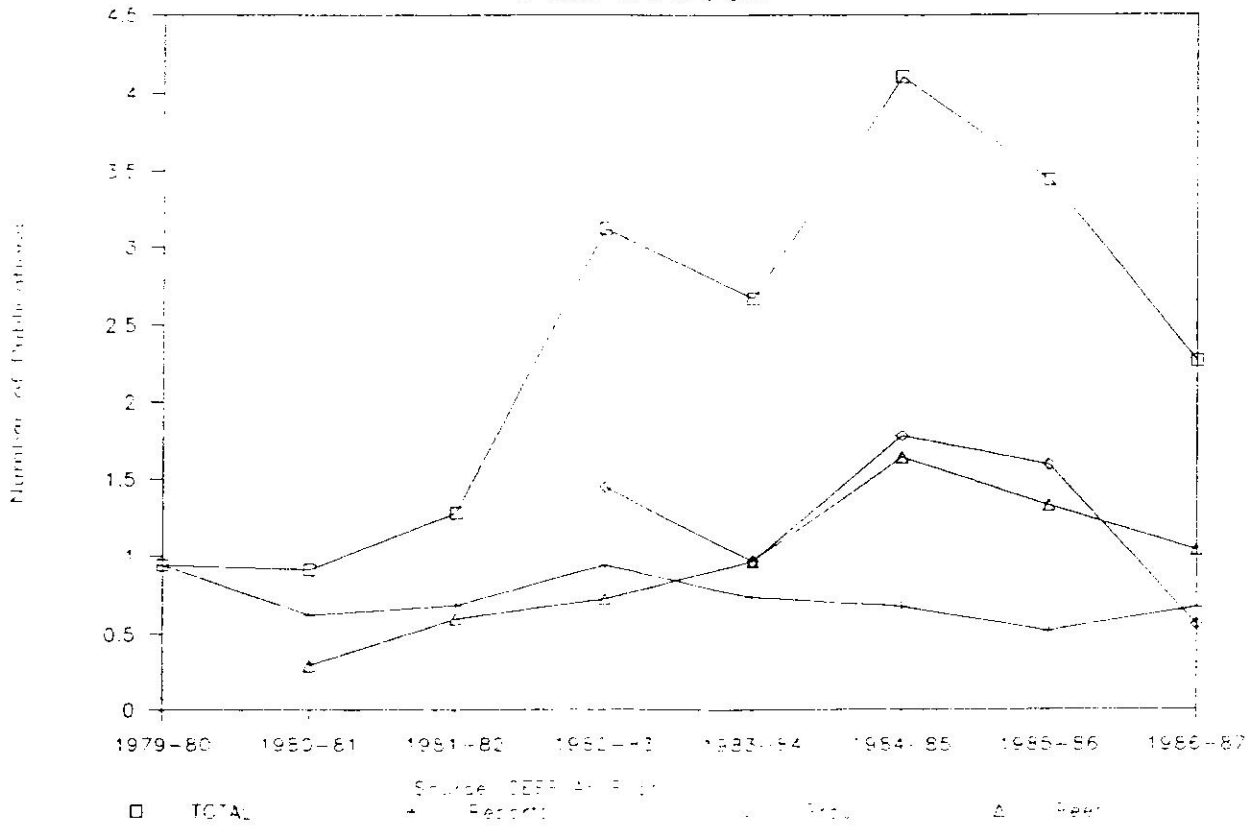


Table 3.
 "SIMPLE" METHODOLOGY
 TOTAL CEER PUBLICATIONS

FY	REPORTS	PAPER	PEER	TOTAL
1979-80	33	NA	NA	33
1980-81	36	NA	17	53
1981-82	24	NA	21	45
1982-83	31	48	24	103
1983-84	22	29	29	80
1984-85	19	50	46	115
1985-86	14	43	36	93
1986-87	18	15	28	61
Mean=	24.6	37.0	28.7	72.9

Source: CEER Annual Reports

Table 4.
 "SIMPLE" METODOLOGY
 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	0.9	2.0	NA
1981-82	3.0	1.4	1.6	NA
1982-83	6.9	1.6	2.1	3.2
1983-84	4.4	1.6	1.2	1.6
1984-85	7.2	2.9	1.2	3.1
1985-86	6.2	2.4	0.9	2.9
1986-87	4.1	1.9	1.2	1.0
Mean=	4.5	1.8	1.4	2.4
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	0.9	NA	NA
1980-81	0.9	0.6	NA	0.3
1981-82	1.3	0.7	NA	0.6
1982-83	3.1	0.9	1.5	0.7
1983-84	2.7	0.7	1.0	1.0
1984-85	4.1	0.7	1.8	1.6
1985-86	3.4	0.5	1.6	1.3
1986-87	2.3	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

Productivity 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.

(Fig. 12) (Fig. 13)

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. To do so would

Figure 12

TOTAL PUBLICATIONS PER PHD PER \$1

Current and Real Dollars

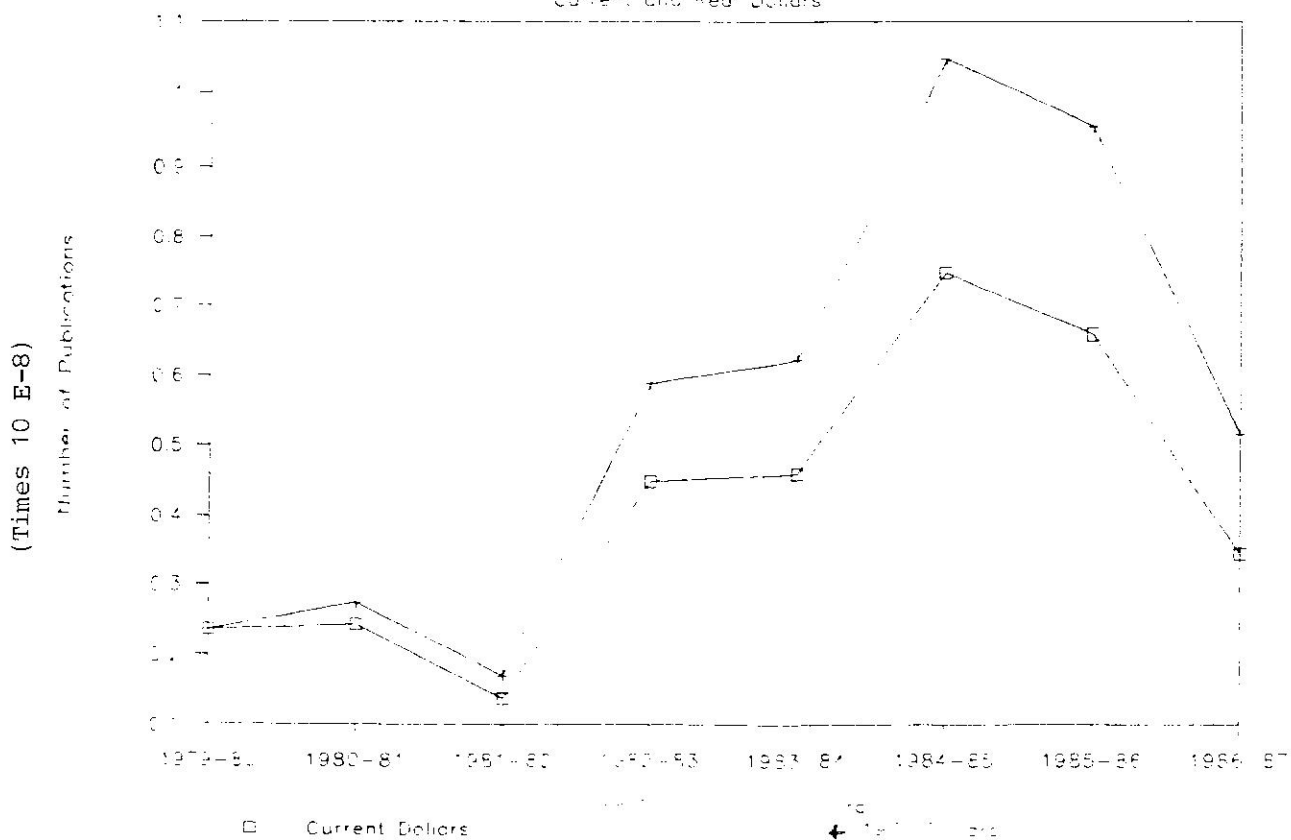
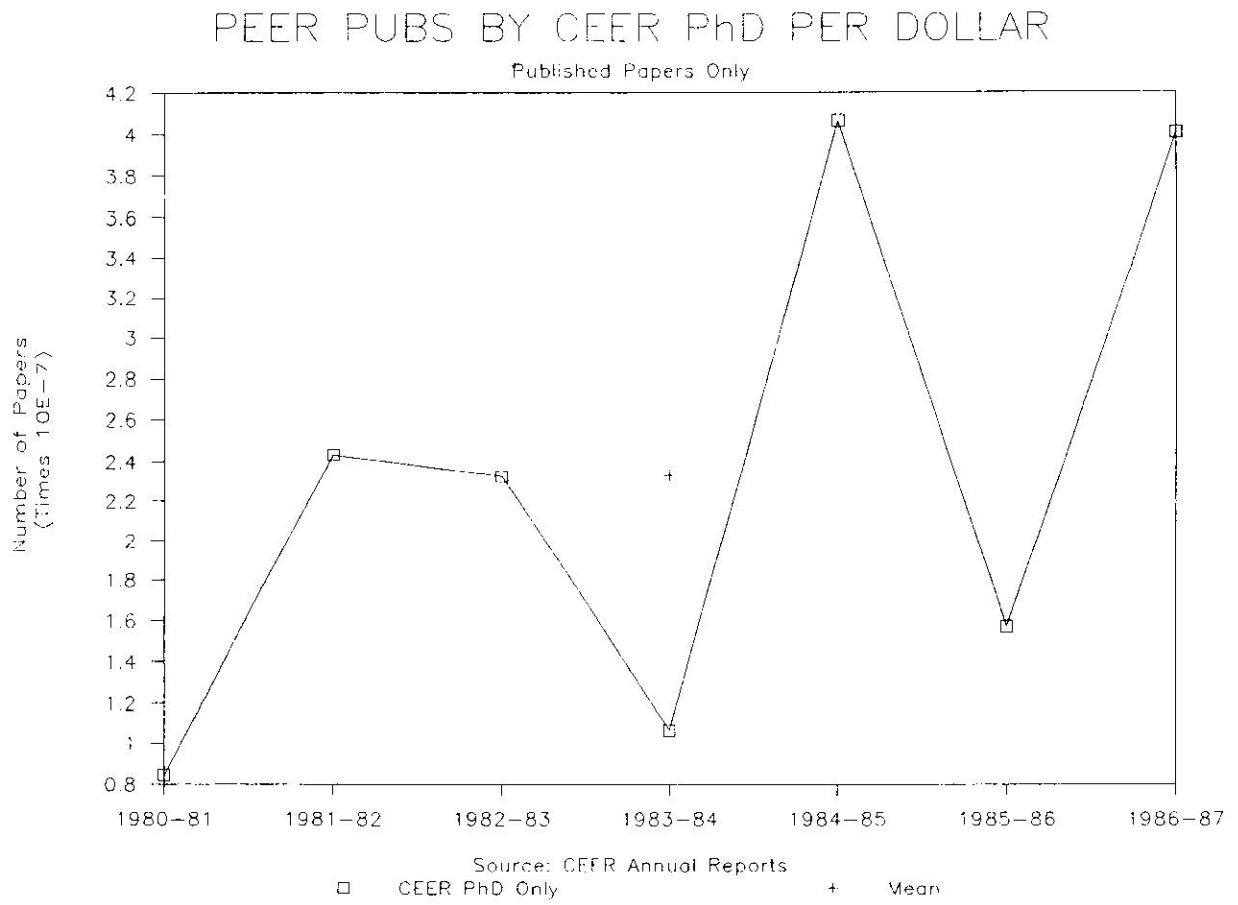


Figure 13



render analysis difficult, given multiple authorship²⁹ 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

²⁹Each 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.³⁰ 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.

Hawaii Natural Energy Institute. Annual report contains no staff or publications count data. This is a "networking" center.

Institute for Energy Analysis, Oak Ridge Associated Universities, closed. It is currently managed by the EERC. Annual reports were published, but contain no total budget data. Data are presented.

Los Alamos National Laboratory. No productivity data pti.

New Mexico Solar Energy Institute, New Mexico State University, Las Cruces. No useful annual report pti.

Oak Ridge National Laboratory. Data set: ORNL Indicators, 1987. Contains data for selected other national laboratories. Data are presented.

It is noteworthy that of all these organizations, data on productivity for most are not readily available. In addition, the Federal Productivity Resource Center reports that they have no similar comparative data. Thus comparative data are presented for the Institute for Energy Analysis and the Oak Ridge National Laboratory only.

³⁰Matching is very important, for there are three center models described by the National Academy of Sciences, *Science and Technology Centers: Principles and Guidelines*, Washington, DC: 1987, pp 12-13. They are, in short, centers (1) organized around a common theme, (2) organized around a common facility, and (3) centers "without walls." These later centers are purely "networkers."

(Fig. 14) (Fig. 15)

Figures 14 and 15 compare the publication output per Ph.D. of the Institute for Energy Analysis (IEA) with CEER. The IEA is a good match for CEER, for while their staff was approximately twice that of CEER's, they maintained in-house facilities and equipment. They had a strong policy emphasis. IEA also had numerous part-time and adjunct staff, as well as a number of visiting scholars in residence. It had two offices, one in Oak Ridge, the other in Washington, DC. The IEA also published in-house reports, contractor reports, articles, papers, proceedings, etc. As is shown in Figures 14 and 15, publication output per staff Ph.D. by the two organizations varied, but the differences are not great.³¹

But IEA had no base funding. Its first director (later distinguished senior fellow) is a renown scientist with extensive management experience (retired director, ORNL) and ties with DOE. As energy funding declined, they tried to shift their programs to defense issues, a natural swing 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 "productivity" compares well against ORNL and other national laboratories, even if the figures found in Table 2 are used.

(Fig. 16a) (Fig. 16b) (Fig 16c)

It should also be noted that there is a great difference between staff sizes. ORNL's Energy Division is given at more than 165 FTE's in its fiscal year 1985-86.³² Figures 17(a) and 17(b)

³¹Chi square was not significant for either peer or total at the .05 level. "N" is too small for other, more powerful tests.

³²ORNL, Energy Division Annual Progress Report for Period Ending September 30, 1986, ORNL-6380, Oak Ridge, June 1987, ch 8.

Figure 14

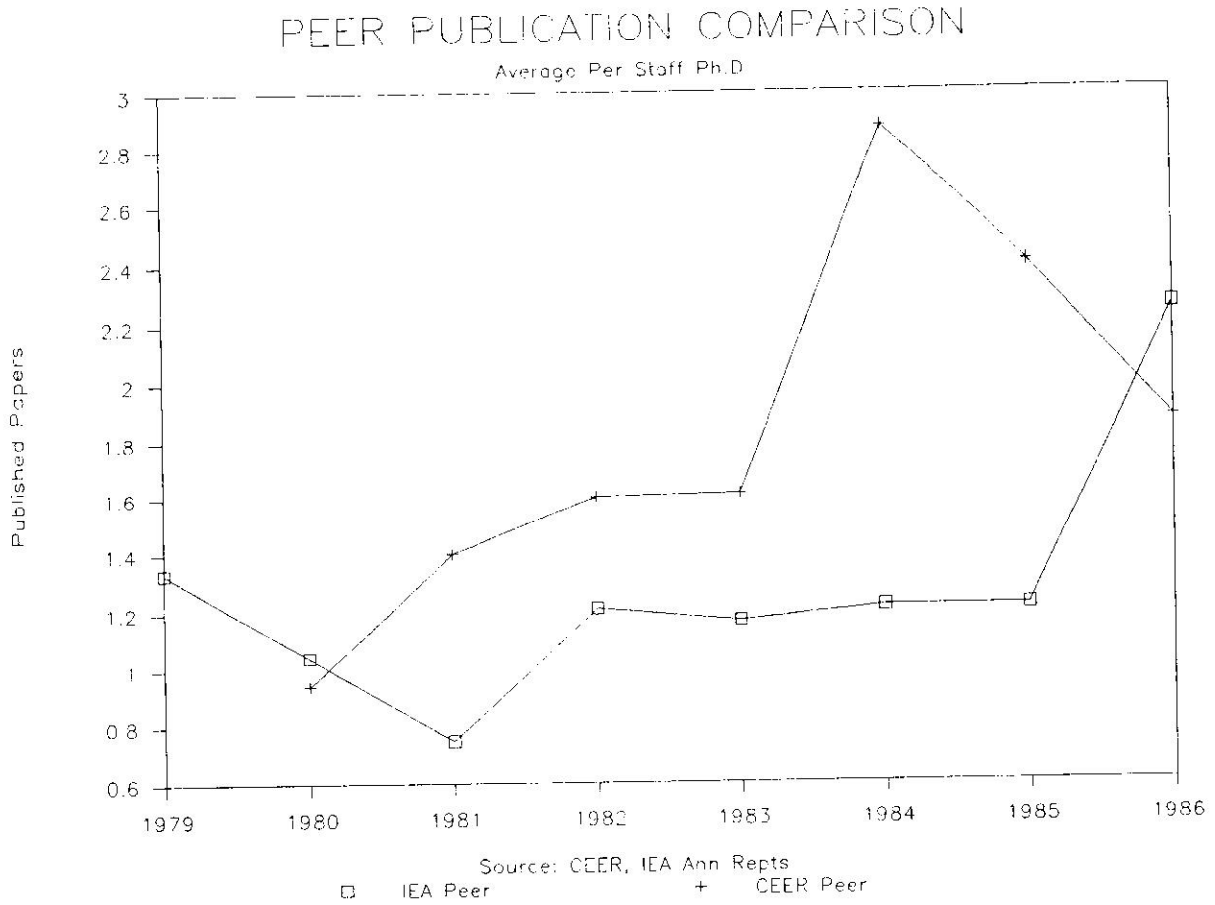


Figure 15

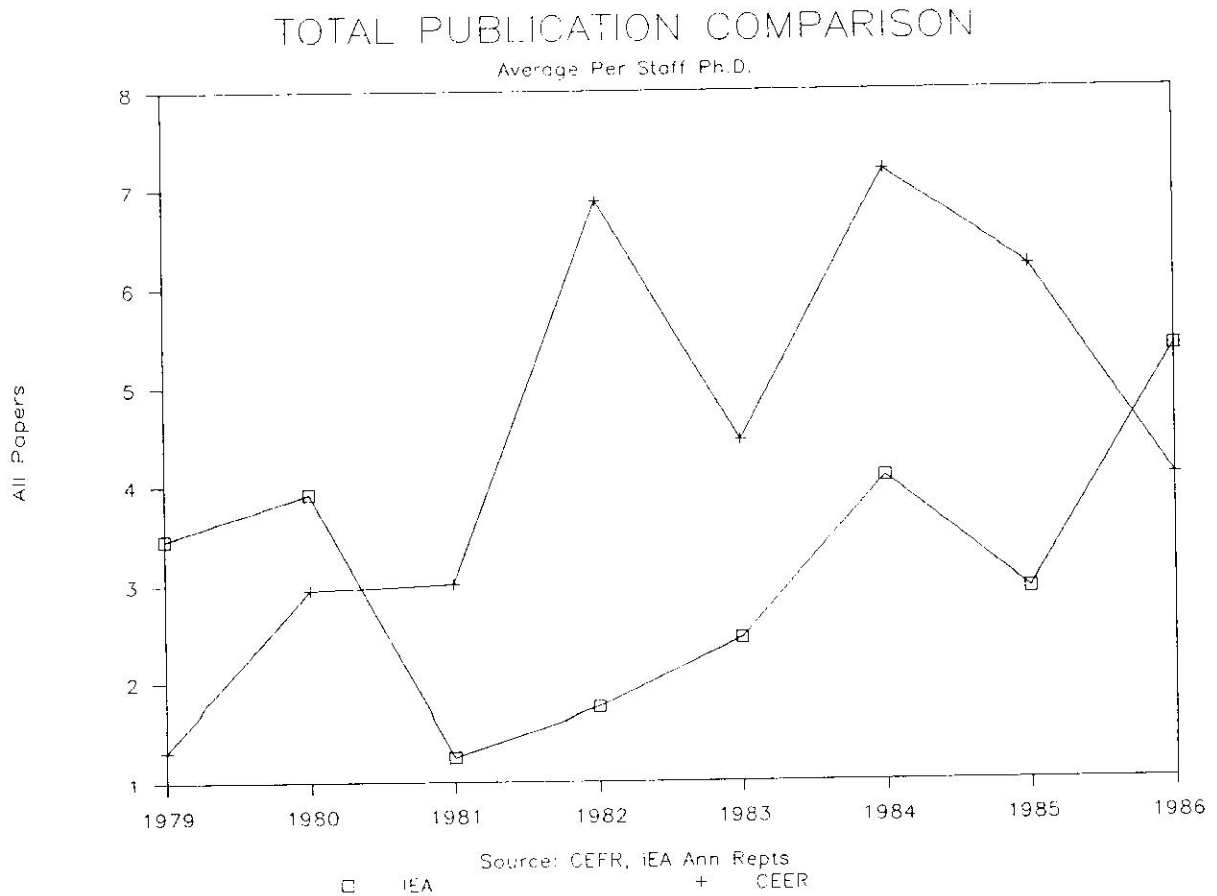
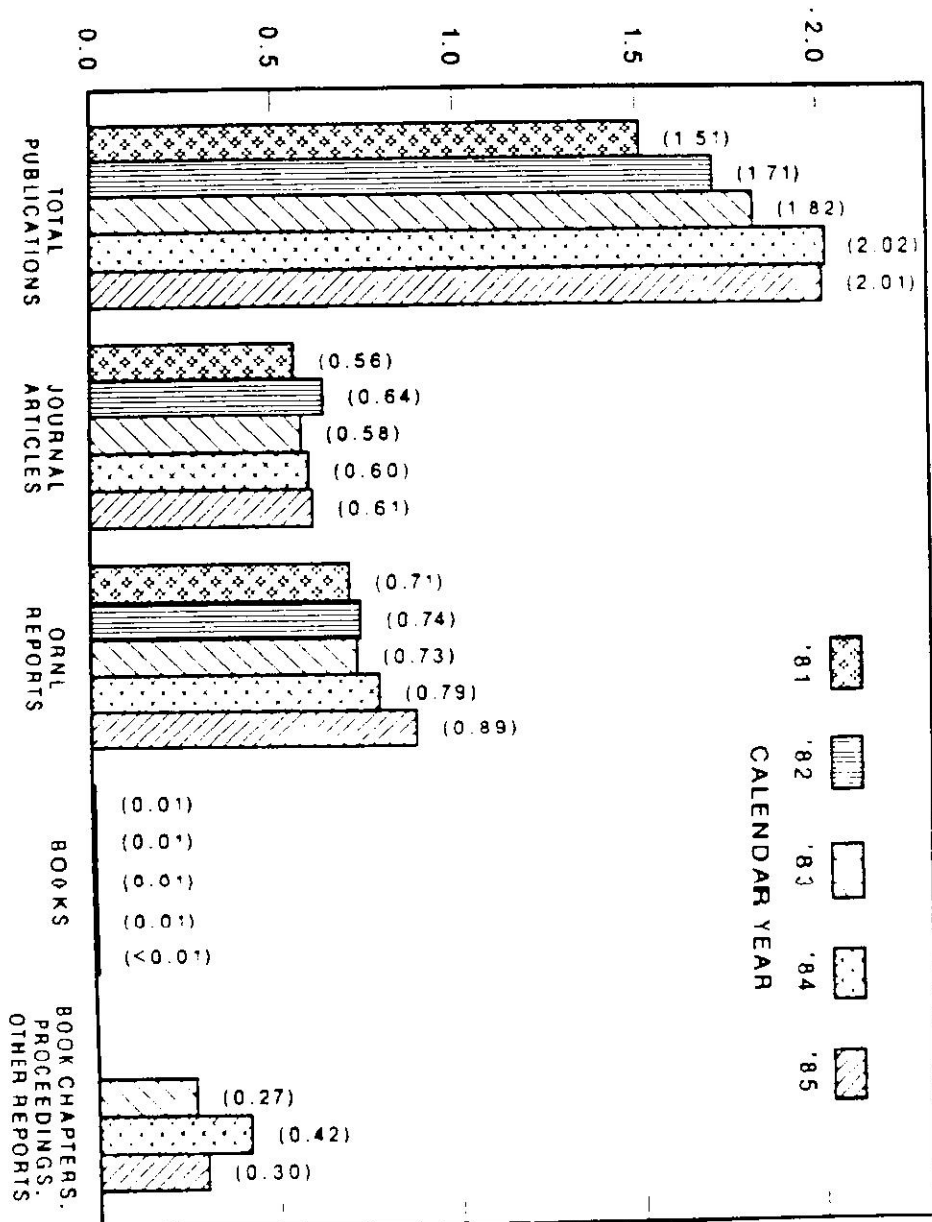


Figure 16(a)

RESEARCH DIVISIONS' PUBLICATIONS PER S&T FTE



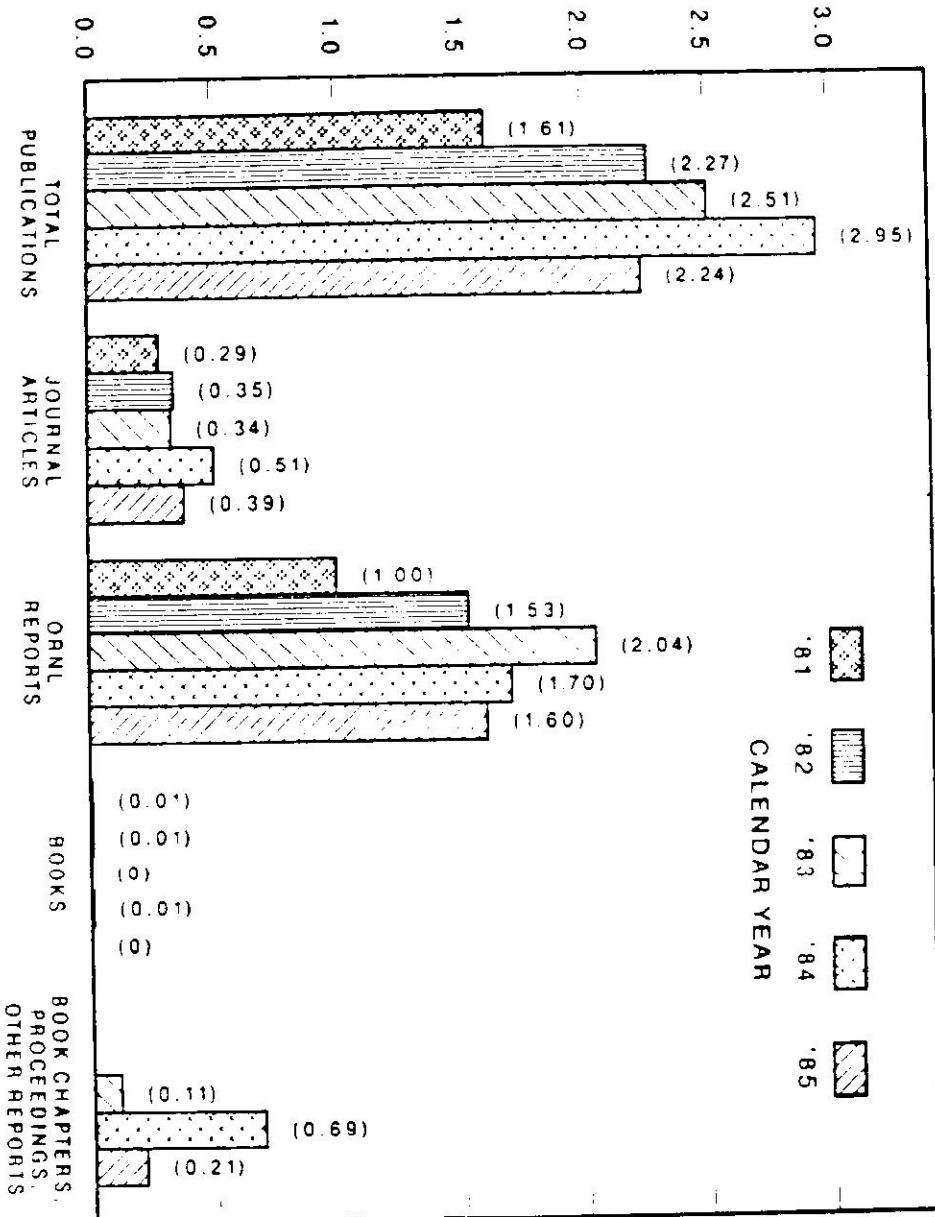
See Table A.55

ORNL-DWG 85C-8972R

The average ORNL researcher authors about two publications per year. The number of journal articles per S&T FTE has remained close to 0.6, but the number of ORNL reports per S&T FTE jumped from 0.71 in 1981 to 0.89 in 1985. (In the basic sciences areas at ORNL, an average of more than 1.2 refereed journal articles are published per S&T FTE annually.)

Figure 16 (b)

ENERGY DIVISION
PUBLICATIONS PER S&T FTE



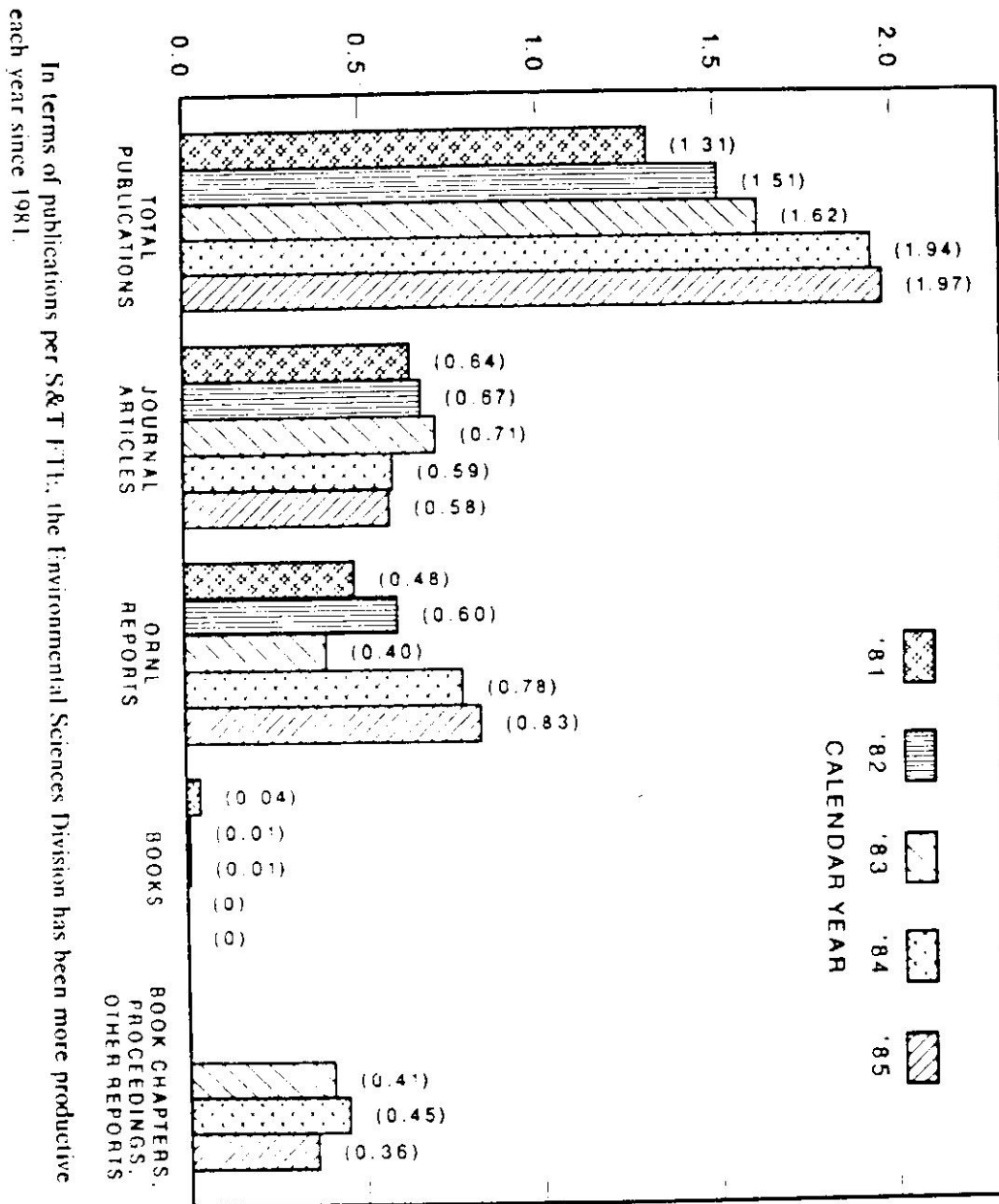
See Table A.55

ORNL-DWG 85C-89778

On the average, the Energy Division has published more than two documents per S&T FTE each year since 1982.

Figure 10.(c)

ENVIRONMENTAL SCIENCES DIVISION
PUBLICATIONS PER S&T FTE



In terms of publications per S&T FTE, the Environmental Sciences Division has been more productive each year since 1981.

See Table A.55

ORNL-DWG 85C-69808

demonstrate the general downtrend in energy funding. These are for fossil programs while CEER's program is primarily in the renewable area, where funding decreases have been even more dramatic.

(Fig. 17a) (Fig. 17b)

CEER/College

It is also possible to compare CEER's output with other UPR units. It must be remembered that the missions and goals of CEER are different from those of academic departments at UPR or any other university. Again, priorities differ, as does the output mix.

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 Mayagüez.³³ Its "Profiles..." document opens with a disclaimer on data accuracy, and notes that data were collected in somewhat different fashions by submitting units, and presumably perhaps by subunits. In any case, there are significant differences between the data presented in the EPSCoR document and in this report for CEER. Figure 18 presents an example of these differences:

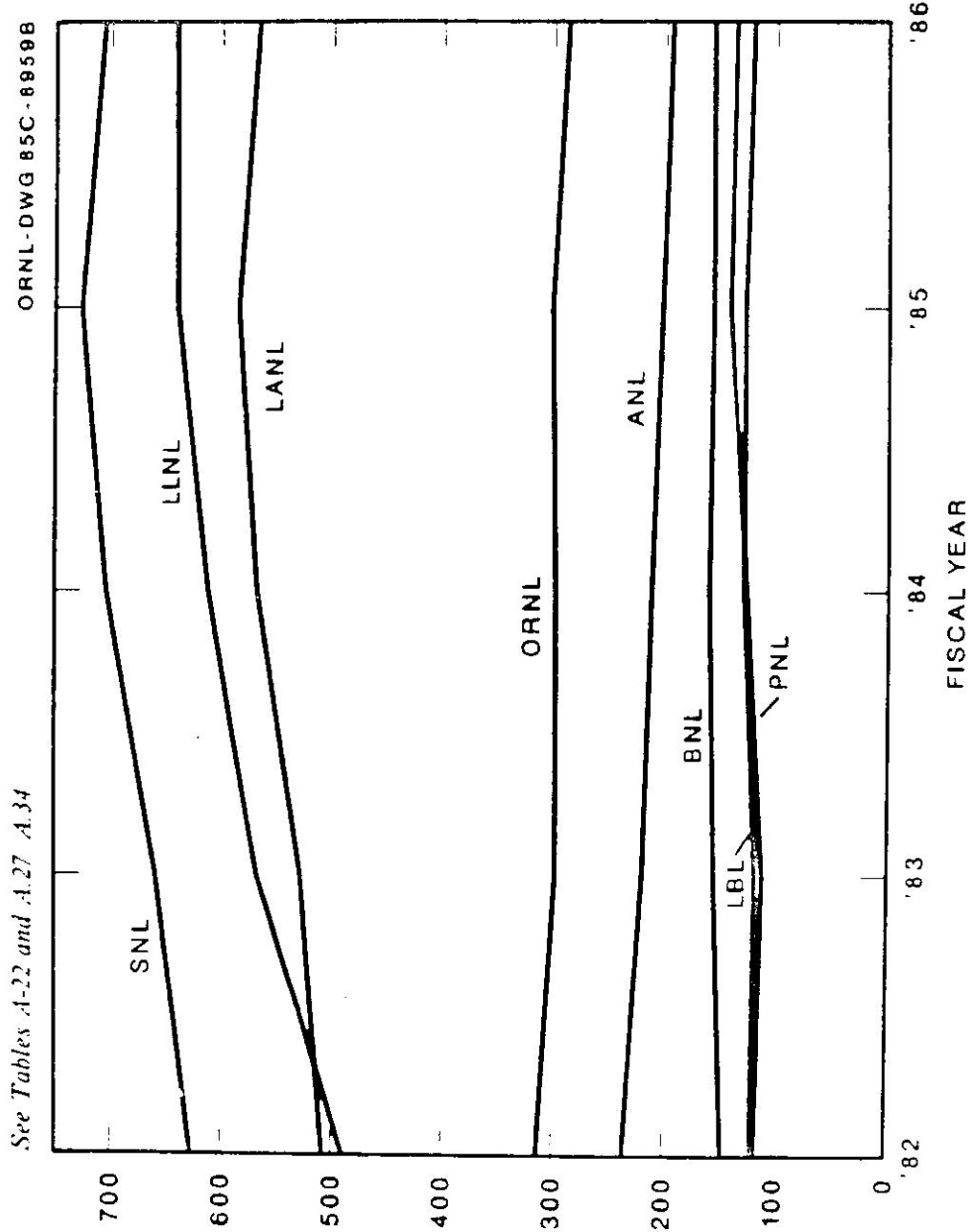
(Fig. 18)

The top line in Figure 18 represents total CEER publications per year, while the line beginning in 1980-81 represents total peer review articles per year, according to CEER Annual Reports. The remaining line is taken from the unnumbered table on page 36 of the EPSCoR document. From an examination and close reading of the

³³EPSCoR Ad Hoc Committee, "Profiles of Graduate and Research Institutions Participating in the EPSCoR Program," n.d. [1985?], n.p. [Rio Piedras?]. We would have preferred to have based the analysis in this section on a larger number of documents. However, all efforts to gain access to that data were to no avail: letters and telephone calls were not answered, publications were missing from the libraries, and so on.

Figure 17 (2)

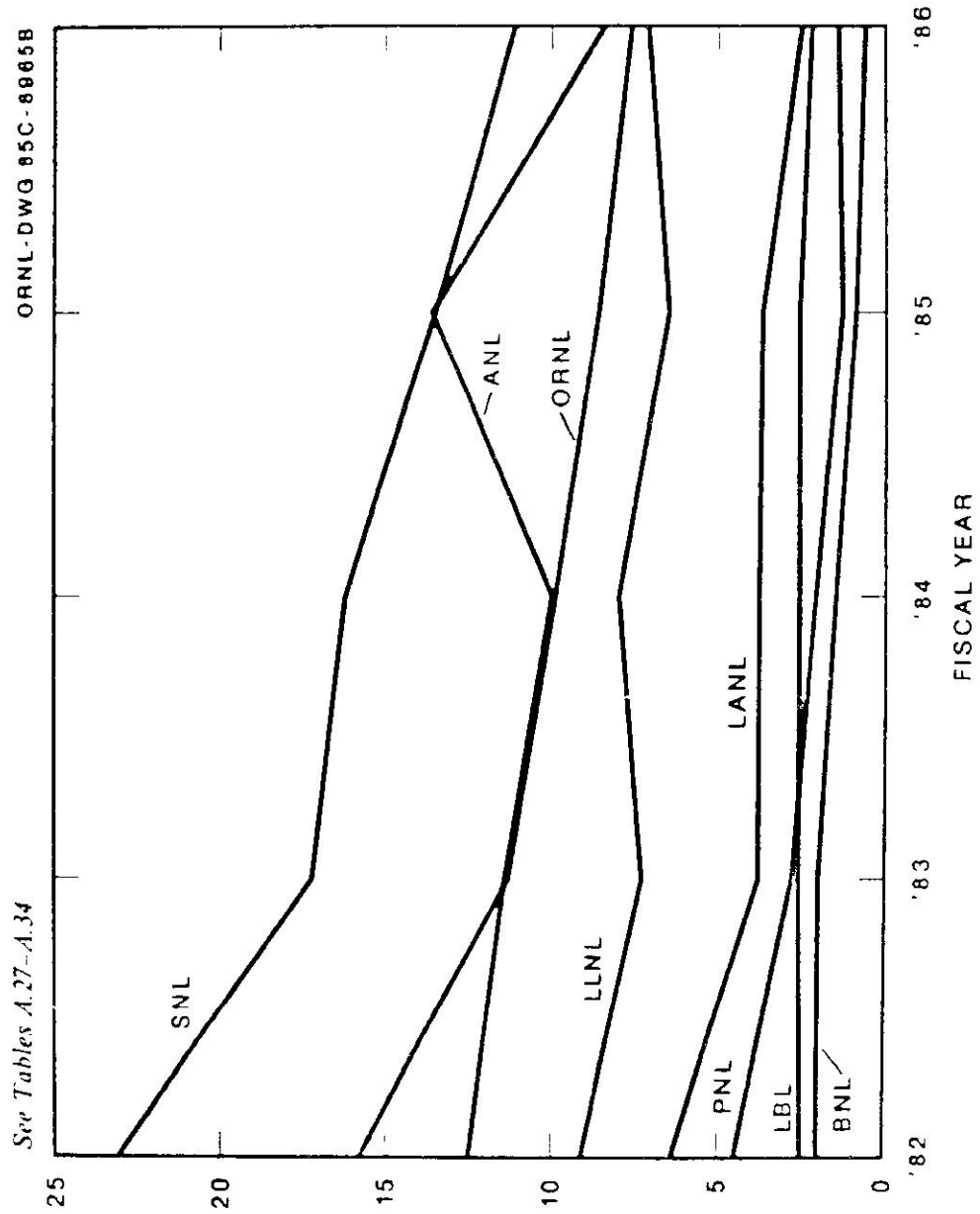
TOTAL DOE FUNDING (OPERATING BO) IN
MILLIONS OF 1986 DOLLARS



After several years of beefing up the defense laboratories' budgets, in 1986 DOE leveled off funding to almost all of the laboratories. (This graph is the first in the annual Market Survey. In this Survey, the operating budgets of DOE's eight major multiprogram laboratories are compared by major program area and by non-DOE sponsors over the last five years. Most of the data for this survey are taken from each laboratory's institutional plans. The 1986 ORNL data are actual costs from the F&M Division.)

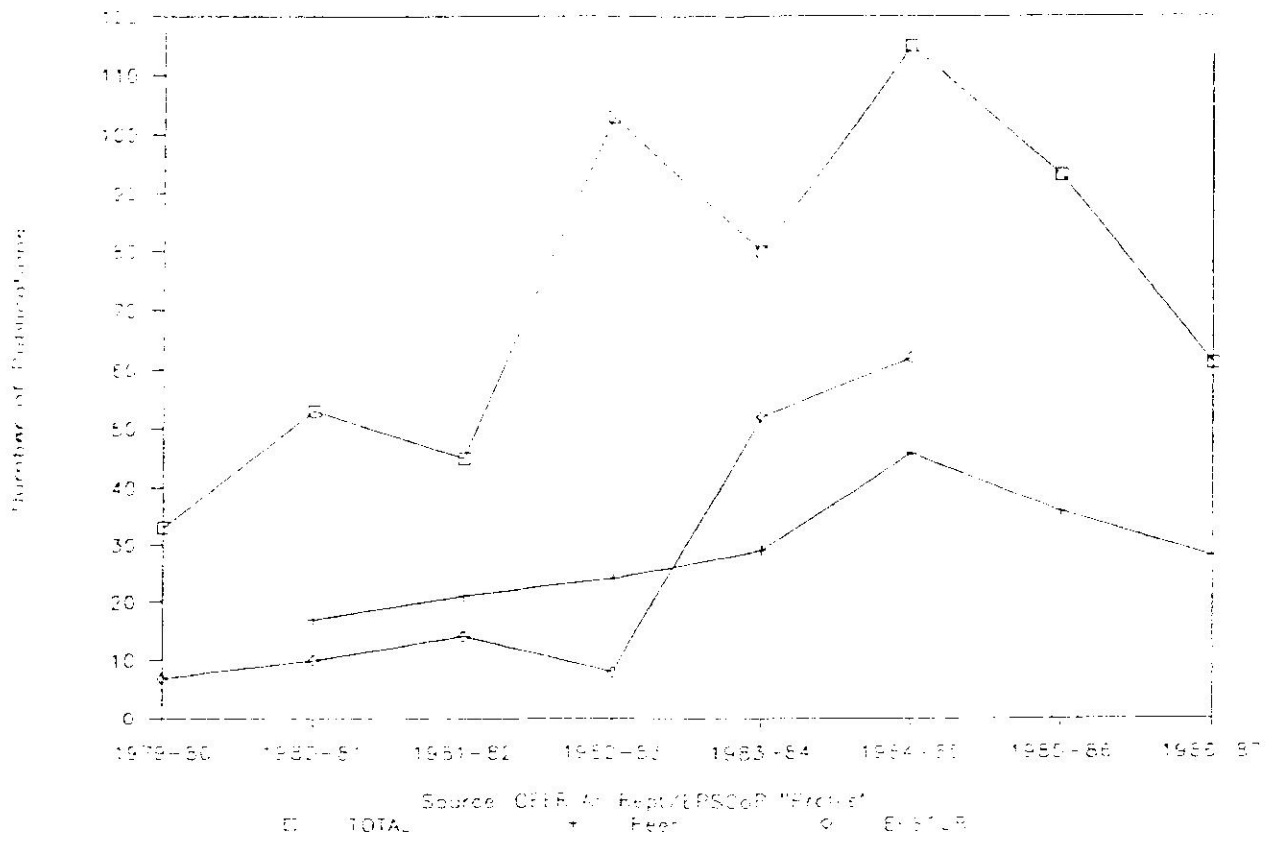
Figure 17(b)

DOE FUNDING FOR FOSSIL ENERGY
(OPERATING BO) IN
MILLIONS OF 1986 DOLLARS



Source: OIL Balance indicators page 81.

CEER PUBLICATIONS



EPSCoR document, it is assumed that their lines reflect peer review articles only.³⁴

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 way by which publications are counted in the EPSCoR document is also unclear. Depending upon the methodology, the potential for multiple counting of a single article having multiple authors is possible. This probably did not occur, and is so assumed. The data for CEER are not subject to this, each paper is counted but once.

(Fig. 19)

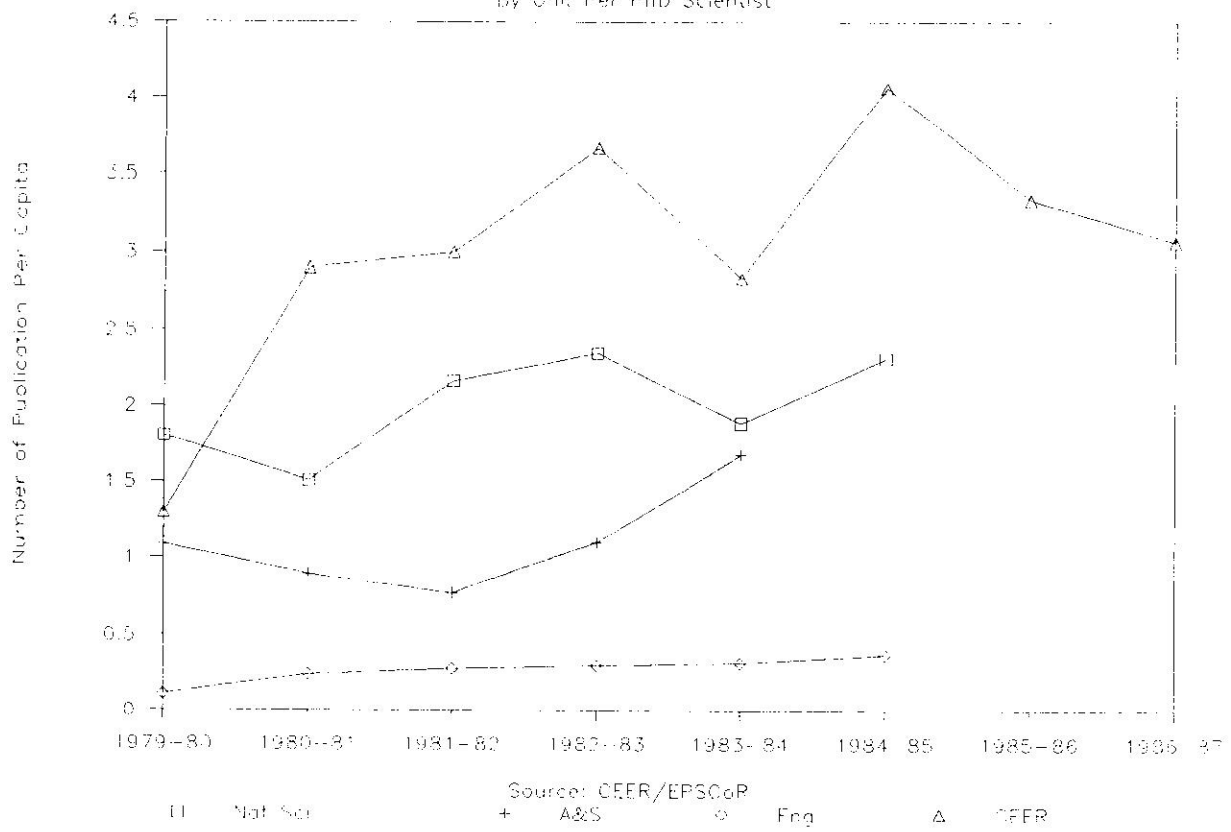
In Figure 19, the assumption can be made that peer reviewed articles and reports should carry equivalent weight; and it is likewise assumed that both of these are included in the data provided for the Colleges of Natural Sciences, Río Piedras; and Arts and Sciences and Engineering, Mayagüez by EPSCoR. 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

³⁴There are, however, 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-Río 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

UPR PEER & REPORT PUBLICATION

By Unit Per PhD Scientist



more than 25 Ph.D. scientists, as is shown in Figure 3.³⁵ In preparation of these Figures, the actual number of CEER employees, as reported in the Annual Reports was employed, rather than "31".

The assumption can be made that peer reviewed papers and reports are not equal, and should not so be treated. It is also assumed - a very difficult assumption to make - that peer review 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, Figure 21 for Ph.D.'s only. The data in Figure 20 include the number of graduate students in various departments, who probably fulfill many of the same roles of UPR MS personnel (many of whom are, likewise, graduate students) and who are recognized as contributors to the research process.³⁶

(Fig. 20) (Fig. 21)

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 peer review articles only are considered. If any of the three identified possible errors in the EPSCoR data occurred, CEER compares even more favorably.

³⁵EPSCoR, "Profiles..." p. 14.

³⁶Note: 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. Although we have made numerous attempts, we have been unable to locate a source for faculty size over time. There are, therefore, at least three possible means whereby the EPSCoR data are inflated for the Colleges.

Figure 20

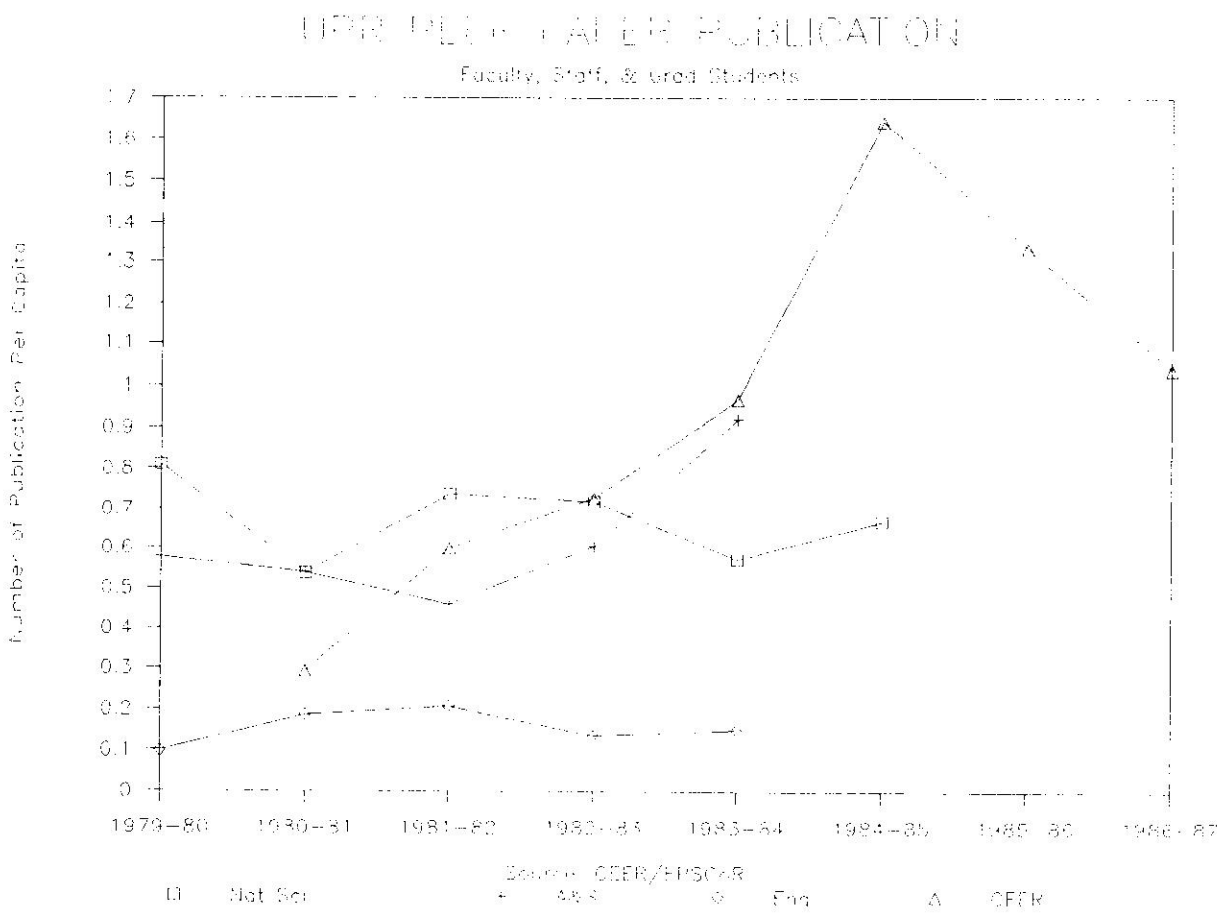
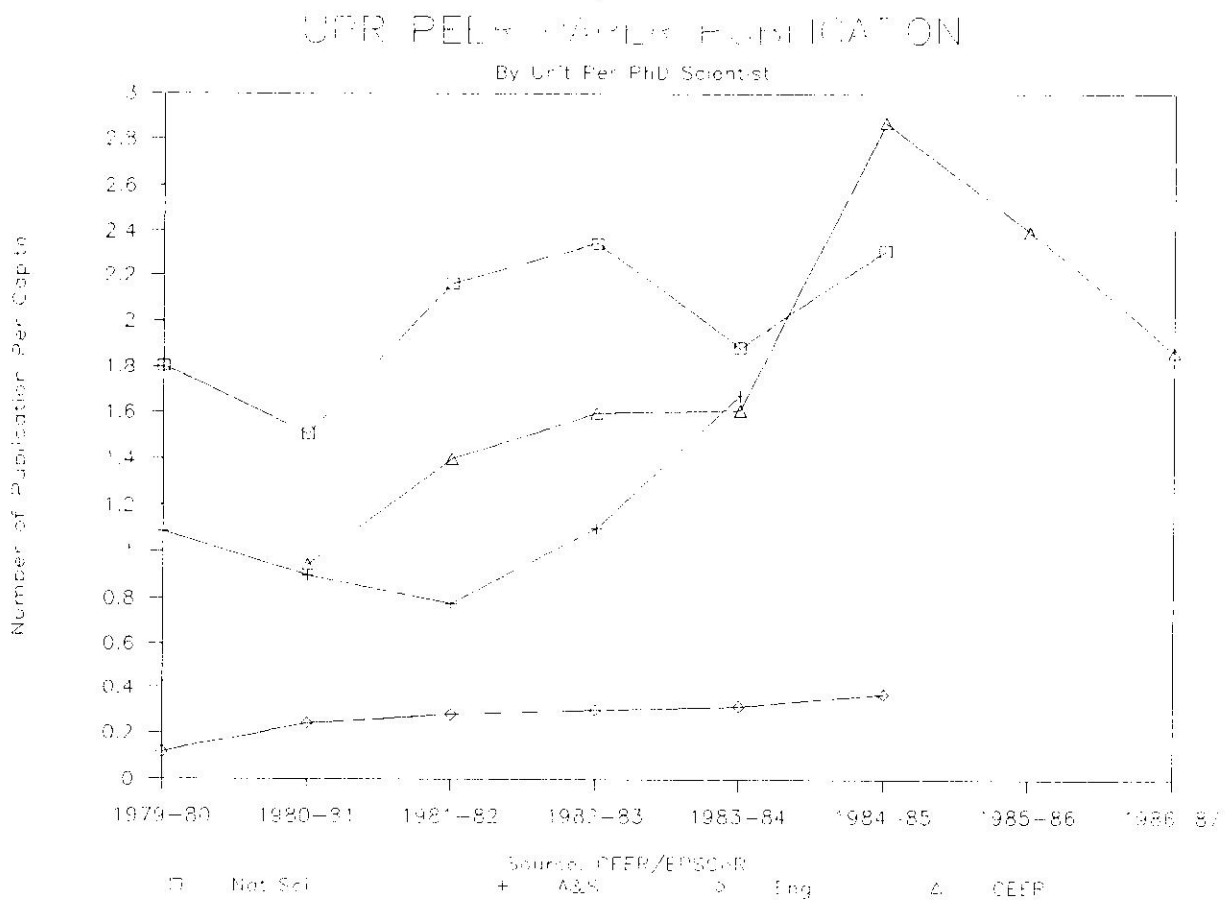


Figure 21



The ability to attract outside, competitive funding is likewise an indicator of productivity.

(Fig. 22) (Fig. 23)

Figure 22 is a graph of the competitive funds received by various units of UPR per Ph.D. In Figure 22 these funds are reported in absolute terms. The plot for CEER compares well in per capita terms. Because of uncertainties and lack of accurate data on the faculty populations of the Colleges, per capita College projections are almost certainly inflated, suggesting significantly greater relative CEER productivity than can be reported here.

Conclusions:

1. CEER Productivity has increased since FY 1979/80. That increase in productivity was maintained even as the transition from DOE to UPR base funding began. The increase in productivity can be measured in a number of ways. These include a successful transition during a difficult funding period and maintaining organizational integrity as programmatic areas changed. CEER has shown 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.

2. CEER Productivity appears to compare well 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. Data in hand are too uncertain and existing methodologies too inadequate for further certainty. Moreover, it is tenuous to make the comparison, at least with academic units.

Figure 2.2

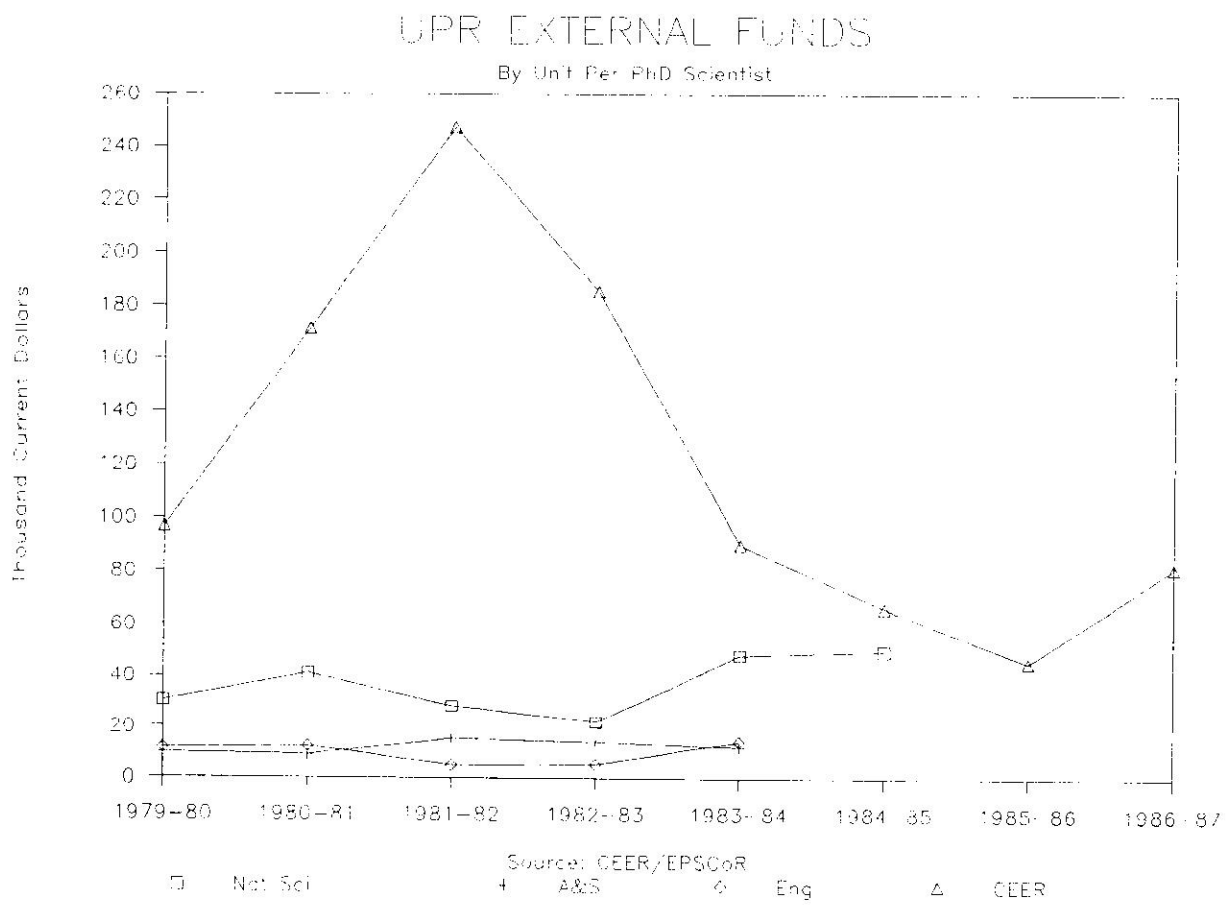
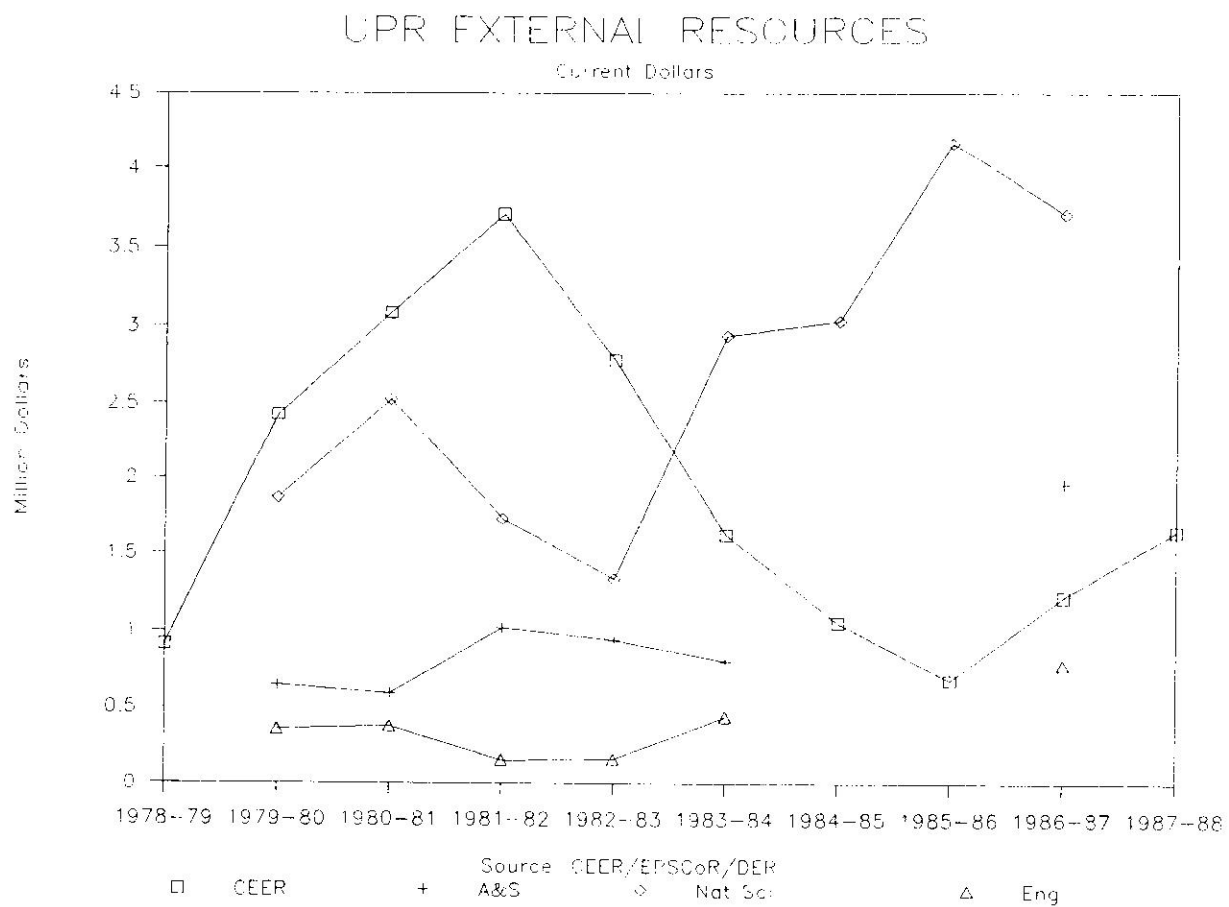


Figure 23



3. CEER has successfully weathered a difficult funding period. Competitive funding is increasing in real terms as well as a percent of total budget. The fact that CEER has maintained its institutional integrity can be attributed to the fact that CEER has had a stable funding base from UPR. It needs to maintain its funding base if it is to continue to be successful. It should also be noted that CEER productivity in recent years is greater than during the 1970s, despite the fact that institutional funds are currently half the level of the 1970s, in real terms.

4. 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 sum, those factors capable of measurement in 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.

