Performance Measurements for the CREWES Project

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ABSTRACT

Performance measurements are a useful tool for measuring and encouraging progress towards desired goals. The mandate of the CREWES Project is to educate students, and to produce valuable research results. We have designed a quantity that encapsulates our progression towards these two aims. Research results are evaluated primarily on the basis of publications, as documented studies of research organizations indicate that this is amongst the most reliable indicators of output. Numbers of graduates are the foundation of the measure of meeting the educational goals.

The output measure, as a function of time, shows that The CREWES Project appears to be on track with respect to succeeding in its two-fold mandate. In addition, while output has risen steadily over the lifetime of the project, productivity has remained fairly constant. Additional financial analysis suggests that diffusion of CREWES technology has followed a pattern typical for new technology offerings in the marketplace, and that both revenue and costs can be correlated to external factors.

INTRODUCTION

The CREWES Project has been conducting geophysical research for 15 years. The Project has enjoyed numerous successes and helped train several excellent geophysicists. Nonetheless, as the Project has attracted considerable funding and effort, it is worthwhile to try to define and measure its productivity.

Performance measurements are a managerial tool that can assist in controlling outcomes in an organization. The value inherent in measuring performance derives from the commonly held belief that managers can only control those elements of productivity that are measured. Further, performance measurements act as incentives, as employees tend to accomplish the goals that are measured.

One use of performance measures is to demonstrate how the organization as a whole is progressing towards achieving desired goals. Typically, measurements at this scale are useful for senior managers, who desire an aggregate appraisal of the productivity of their workforce; assessment of compliance with policies and procedures; and as a measure of the appropriateness of internal systems and procedures. Further, these measurements are useful for communicating results to external stakeholders.

Because performance measurements drive activities, metrics must be closely aligned with organizational strategies and objectives. At the same time, to ensure transparency in the measurement process, metrics must be: based on data that are straightforward to measure and to communicate; a natural consequence of the organization's operations; and, completely under the control of the entities that are being assessed.

There is often confusion regarding the distinction between performance measurement and performance-based management. Simply put, performance measurement quantifies actual levels of performance and compares these to targeted levels, whereas performance-based management uses performance measurements to manage and improve performance. In other words, performance measurement is a key input to performance-based management.

In this note, we examine 15 years of productivity by CREWES faculty, staff and students to extract parameters that encapsulate the two-fold mandate of CREWES, which has always been to mentor and graduate well-educated students with practical experience, and to be a primary research and development leader in supplying new exploration ideas and recovery technologies. We begin with a discussion of criteria for selection of appropriate metrics, and a justification of our measurement scheme. We follow this with a presentation of some results, in turn followed by an analysis of output, revenue trends, and productivity.

DESIGNING A PERFORMANCE MEASURE

We attempt to measure elements of output that are proportional to the complementary goals of training and researching. Our basic premise is that productivity can be measured as a weighted sum of individual contributions to each (or both) of these goals. In the following we describe our scheme for selecting and weighting these individual contributions.

Counting publications as a method for measuring research productivity was first suggested by Nobel Laureate William Shockley (Shockley, 1957). This was done as the basis for comparing productivity of individual scientists. Later studies noted that publication counts are also a reliable metric for evaluating a research organization collectively (see e.g. Quinn, 1960, and Hodge, 1963). Thus, an important component of our performance measure is the number of publications, in which we include refereed journal papers, non-refereed papers, CREWES research reports, patents, and software distributed to sponsors. Each of these types of publications is weighted according to the impact. The primary measure of educational output is the number of graduates. Additionally, there are two outputs that encompass both education and research. The first of these is data acquisition which typically involves student participation in survey design, acquisition, processing and interpretation, as well as some experimentation regarding sources, receivers and layout. The second of these is awards, which represents successful collaboration between students, staff, and faculty collaboration. We seek a quantitative indicator and suggest that output (education and research combined) might be measured as:

$$\mathit{Output} = 1.5 \text{ x } (N_{\text{surveys shot}} + N_{\text{awards}}) + 1 \text{ x } (N_{\text{refereed publications}} + N_{\text{patents}}) + 3 \text{ x } N_{\text{students graduated}} + 1/3 \text{ x } (N_{\text{non-refereed publications}} + N_{\text{conference presentations}} + N_{\text{conference presentations}} + N_{\text{programs released}}). \tag{1}$$

The weights are derived somewhat subjectively; however, it should be noted that this weighting scheme follows the NSERC framework for rating professional contributions (see e.g. www.nserc.ca/forms/instructions/100/080_e.asp), in which refereed publications, awards and training of highly qualified people are weighted heavily, followed by non-refereed publications, and other research contributions (e.g. software). The raw data used to compute the output measure (equation 1) are provided in the Appendix.

RESULTS

The output measure (equation 1) was computed for every year the project has been in existence (1989-2003). The output is shown in Figure 1. This makes evident a general increase in output with time, with an almost three-fold increase over 15 years.

In addition to raw output, it is also useful to normalize the output to the input. The CREWES project has two important inputs. These are revenue and personnel. The personnel are subdivided into two groups, the workforce (comprising faculty members and staff) and students. These inputs are shown in Figure 2. Note that only cash contributions are counted as revenue. Non-cash contributions, such as software and data donations are excluded. As well, the revenue numbers have been adjusted for inflation using the Consumer Price Index.

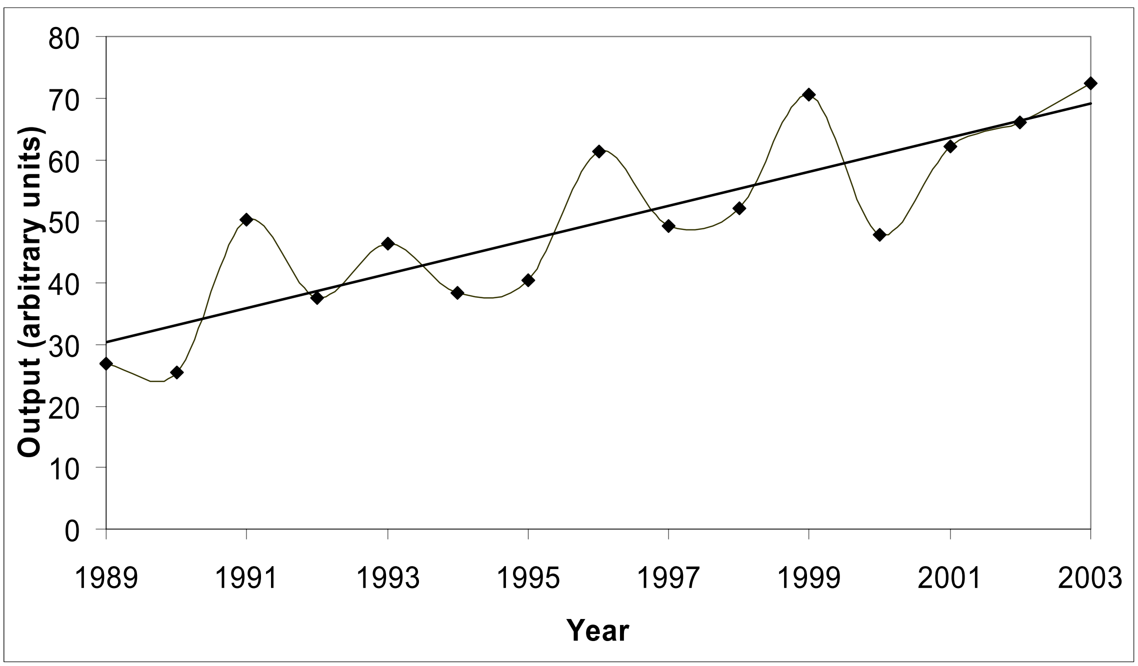

FIG. 1. Output by CREWES personnel over the lifetime of the project. The straight line is the least-squares best-fit first-order polynomial.

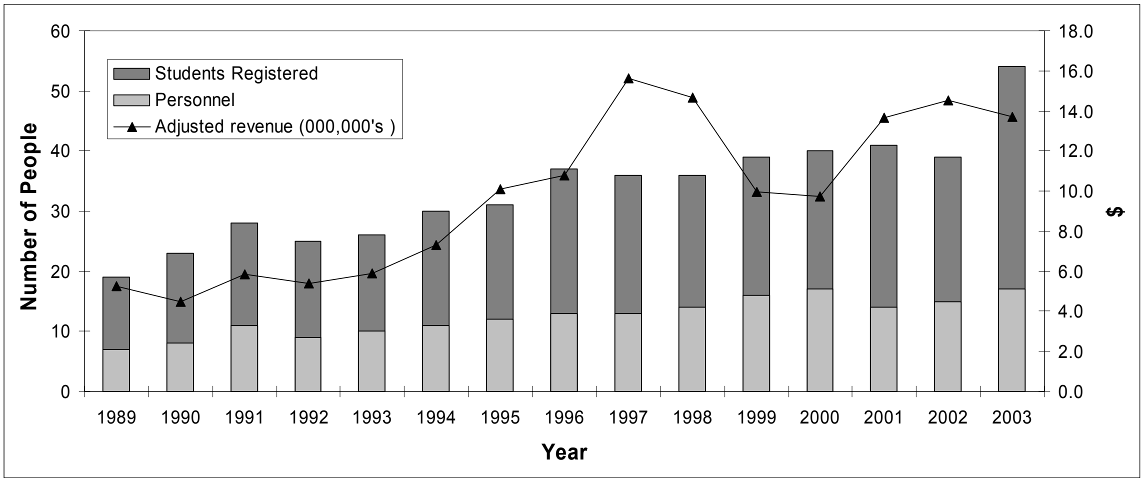

FIG. 2. Counts of personnel (staff and faculty) and students, overlain with inflation-adjusted revenue.

DISCUSSION

Increasing output, with attendant increases in inputs (revenue, personnel, and students) is evident in Figures 1 and 2. In the following, we present some further analysis of revenue growth, and productivity.

Revenue

While revenue is an input, it is useful to examine revenue trends over the duration of the project, as this provides some insight into the success of CREWES, as it does for most organizations. Shown in Figure 3 is the inflation-adjusted CREWES revenue overlain with research and development expenditures (these are expressed both in absolute terms, and in terms of percentage of GDP) made in Canada over the same period. The recent nationwide flattening in R&D spending is, to a degree, mirrored in CREWES Project revenues. As well, it is useful to compare revenue trends with financial performance of the E&P industry. Shown in Figure 4 are CREWES revenues overlain with return on equity (roe) percentages for the exploration and production industry. Running averages of the revenue and roe data (Figure 5) suggest that peaks and troughs in revenue of the CREWES project lag the financial performance of the E&P industry by roughly one year.

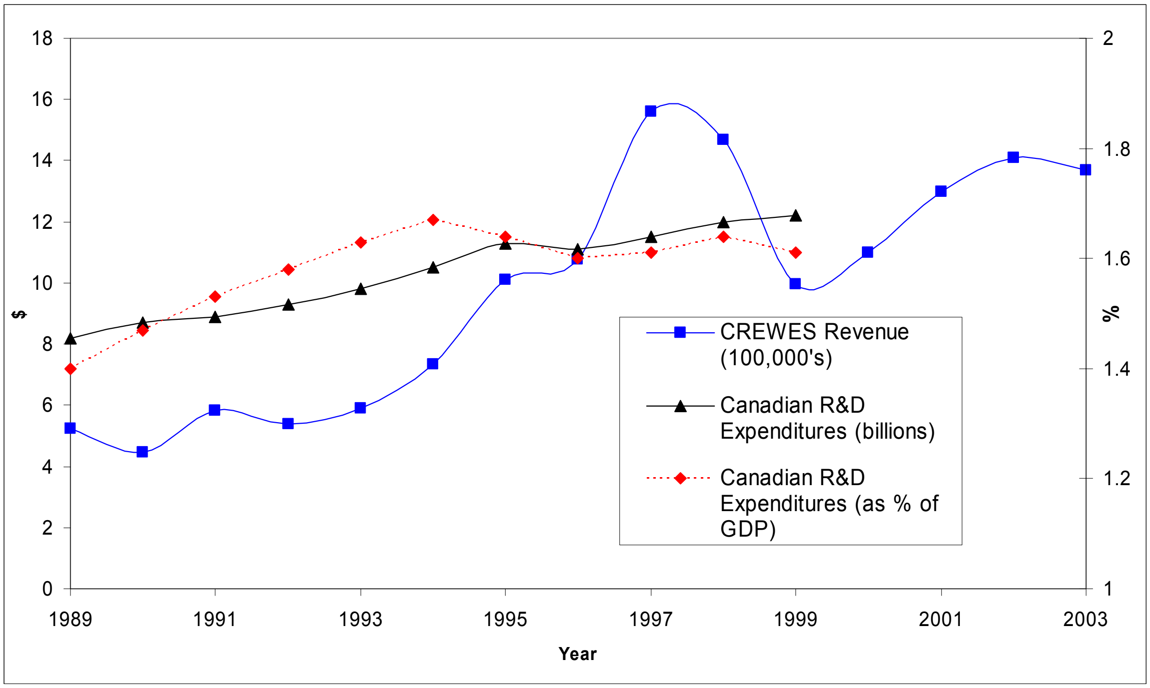

FIG. 3. CREWES revenue growth compared to national trends in R&D spending. National R&D expenditure data are from the NSF website. The national data are only available up until 1999.

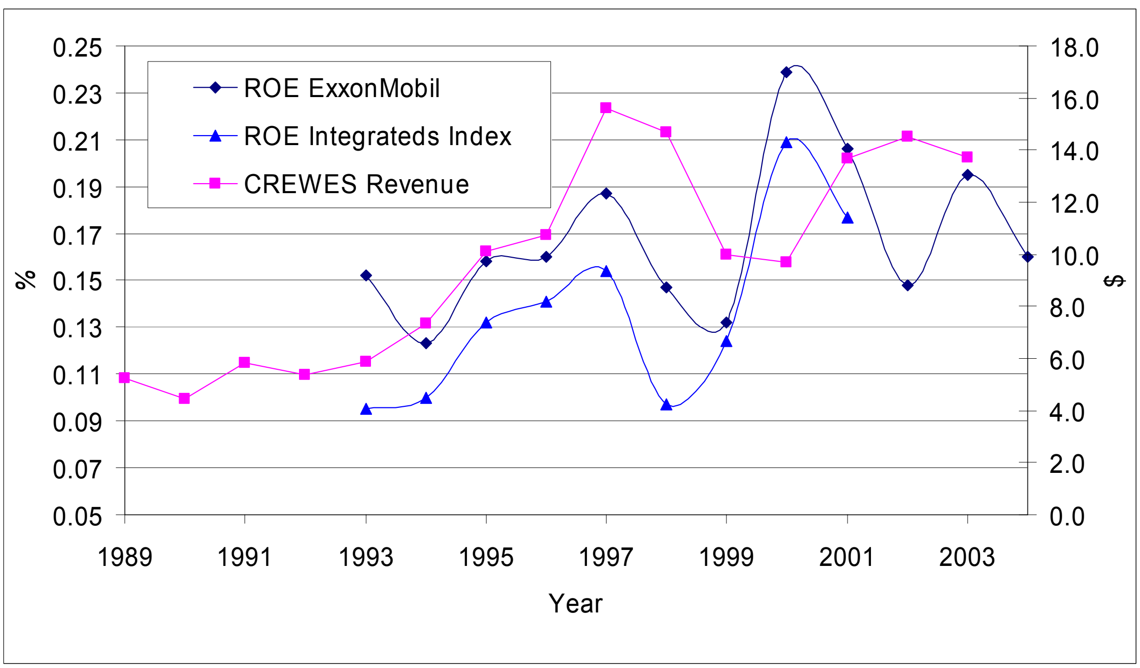

FIG. 4. CREWES revenue growth compared to return on equity (roe) for E&P companies. ROE data are from the Value Line database.

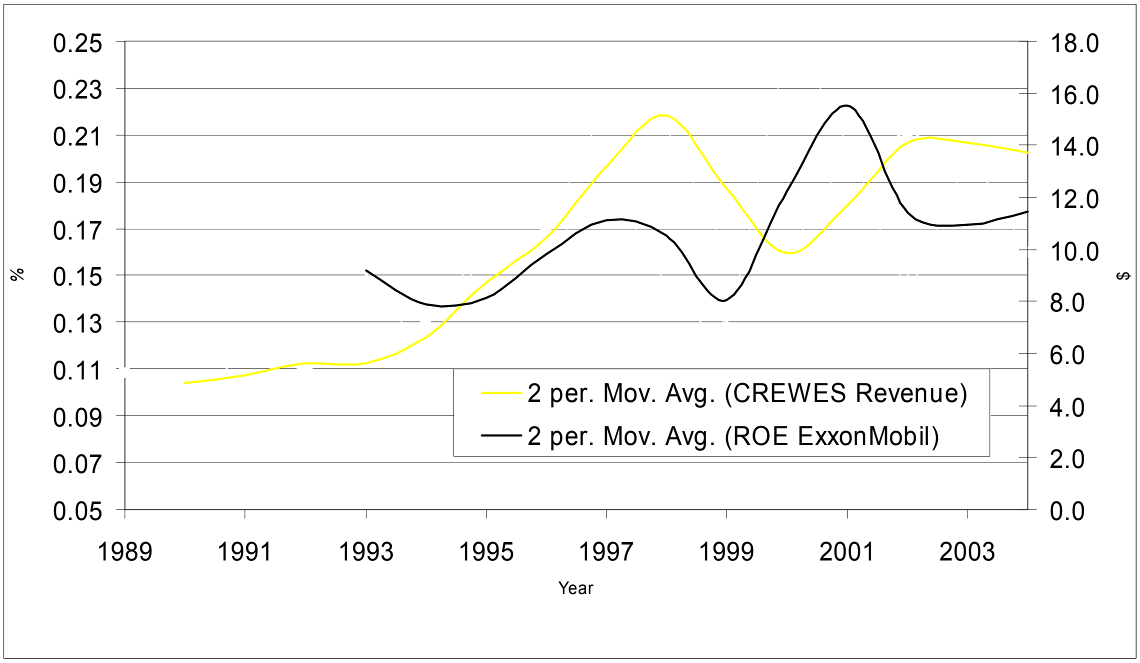

FIG. 5. Running averages of data shown in Figure 4.

It is also interesting to use the revenue data to infer where we are at in terms of the project's lifecycle. That is, cumulative adoption of new technologies is typically an s-shaped curve, as shown in Figure 6. Overlain on the idealized growth curve (shown as a solid black line) is the cumulative revenue of the CREWES project (here cumulative revenue is taken to approximate cumulative adoption). This rough comparison suggests that CREWES, as a type of new-technology offering, has experienced a response from the marketplace that is typically observed for successful technology introductions. Further, the comparison to the idealized growth curve, suggests we are currently in the popularization phase, with some growth on the horizon. It should be noted different technologies undergo this response at vastly different rates. For comparison, shown in Figure 7 are cumulative CREWES revenues, overlain on percentages of market penetration (which is here taken to approximate cumulative sales), as a function of time, for several popular new technologies introduced in the 20th century. Note that the CREWES revenue line exhibits a shape similar to a typical adoption pattern, which is characterized by a short period with relatively gentle slope, followed by a sudden change in slope, which is in turn followed by a period with a considerably steeper slope. The slope break is typically the demarcation between pilot projects and popularization.

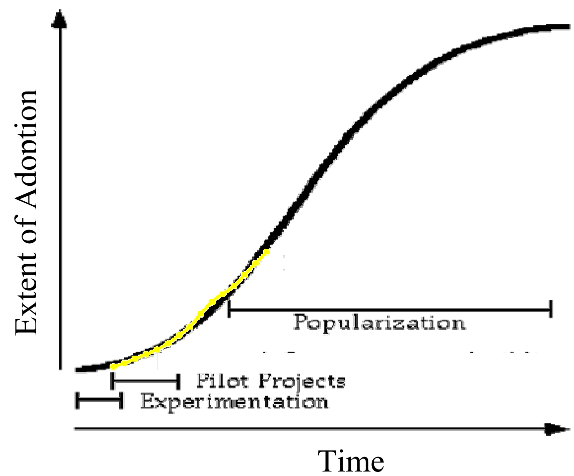

FIG. 6. Idealized s-shaped growth curve for cumulative adoption (after Rogers, 1995), overlain with actual cumulative CREWES revenue for the period 1989-2003.

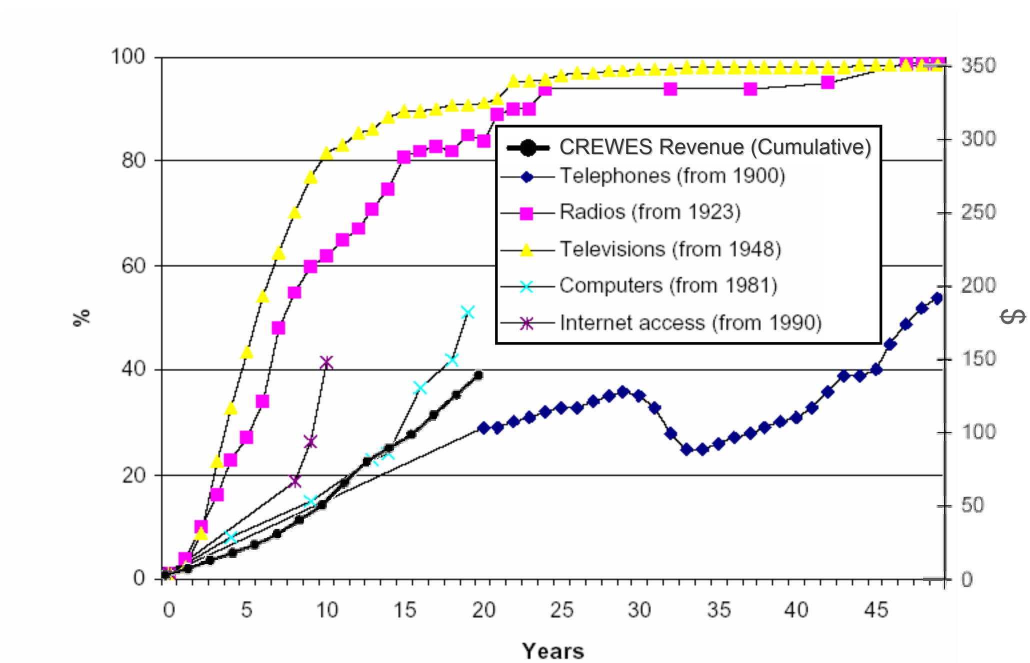

FIG. 7. Comparison between adoption of CREWES and several popular new technologies introduced in the 20th century. CREWES adoption is expressed as cumulative revenues, whereas adoption of the other technologies is expressed as market penetration. These measures are only roughly equivalent, nevertheless there is a marked similarity in the shape of the growth curves.

Productivity

The ratios of outputs to inputs are useful for placing recent results in a historical context. It is also useful to illustrate how the consumption of resources (i.e. sponsorship revenue) has evolved over time.

The ratios shown in Figure 8 suggest that Project growth, with the attendant increased managerial demands on the directors, has not degraded productivity. The decrease in the output/revenue ratio can be explained by an increasing personnel cost (see Figure 9). This in turn can be, at least partly, explained by increasing tuition costs (borne by the Project), and by increasing overhead costs due to reduction on the University's operating expenditures (see Figure 10).

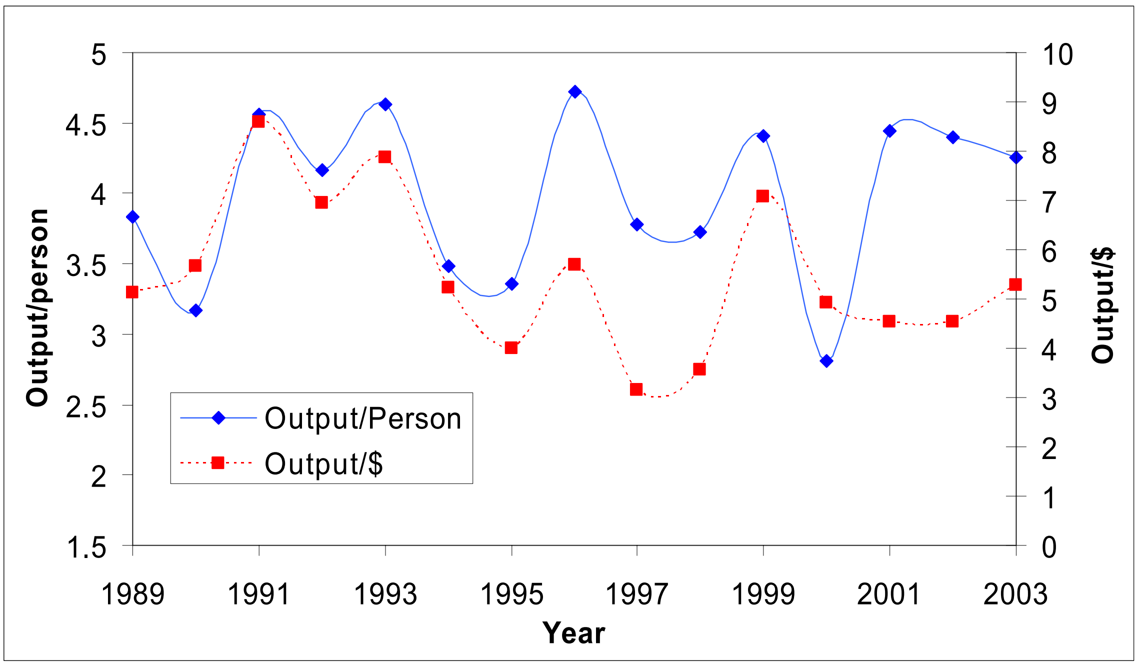

FIG. 8. Output normalized by personnel (staff and faculty) and by revenue.

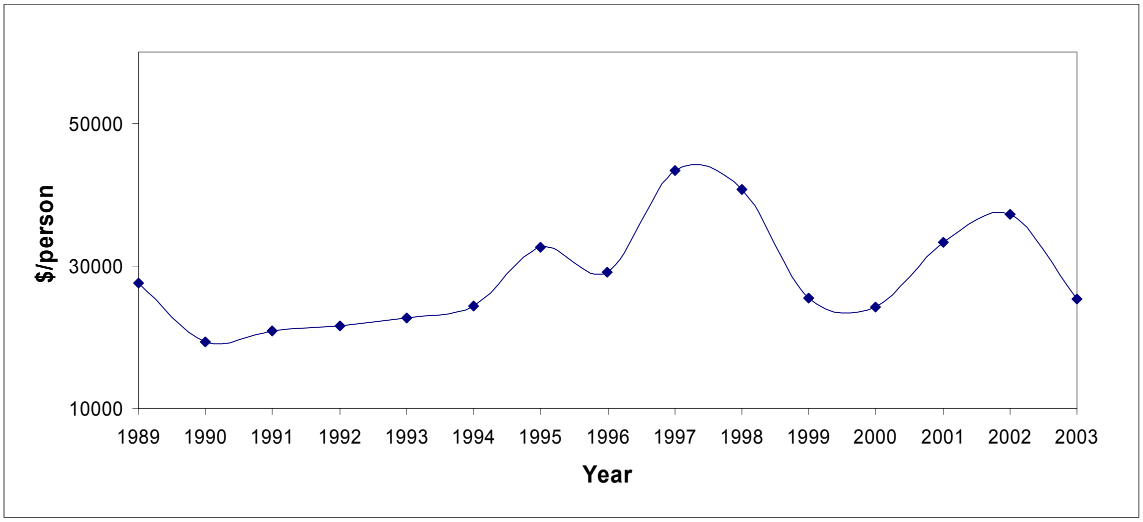

FIG. 9. Revenue on a per person (including staff, students and faculty) basis.

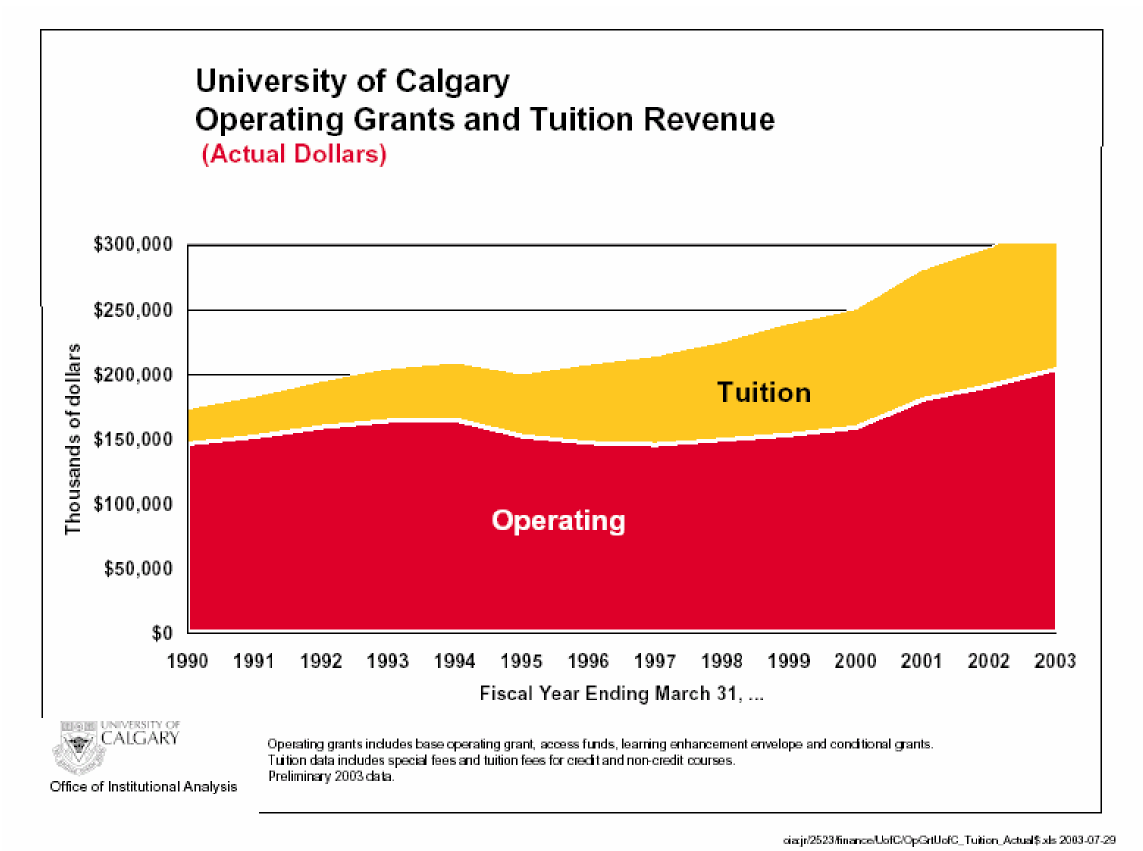

FIG. 10.

SUMMARY

Performance measurements are a useful tool for evaluating the performance of an organization (vis-a-vis desired goals), and for encouraging desired results. CREWES has a two-fold mandate to educate students, and to undertake meaningful research. Thus, we have developed a performance measurement that incorporates these two aims. Research results are evaluated primarily on the basis of publication counts, as documented studies of research organizations indicate that this can be a reliable indicator of output.

The results of our analysis indicate the CREWES Project is succeeding in its mandate to produce research results and to educate students. Additional analysis of revenue growth suggests that diffusion of CREWES technology has followed a pattern typical for new technology offerings in the marketplace. Further, output has risen steadily over the lifetime of the project, and productivity has remained fairly constant.

REFERENCES

Hodge, M.H., 1963, Rate your company's research productivity: Harvard Business Review, **41**, 109-122.

Rogers, E. M., 1995, Diffusion of Innovations, 4th Edition, New York, Free Press.

Quinn, J.B., 1960, How to evaluate research productivity: Harvard Business Review, **38**, 69-80.

Shockley, W., 1957, On the statistics of individual variations of productivity in research laboratories: Proceedings of the IRE, **45**, 279-290.

APPENDIX – DATA USED FOR PERFORMANCE MEASUREMENTS

Year	Faculty	Staff	Adjusted revenue (000,000's)	Students Registered	Peer-Reviewed Publications	Reviewed Expanded Abstracts	Other Publications	Other Abstracts	Research Report Papers	Software Releases	Patents	Awards	Surveys	Students Graduated
1989	3	4	$5.23	12	9	2	1	14	23			1		1
1990	3	5	$4.46	15	5	8		8	27			1	1	1
1991	3	8	$5.84	17	10	11	1	24	35			2	1	4
1992	3	6	$5.39	16	4	8	3	13	35	10		1		3
1993	3	7	$5.89	16	9	6	2	17	32	10		2	2	3
1994	3	8	$7.33	19	6	7	3	11	33	7		0		4
1995	3	9	$10.11	19	3	6	2	14	46	8		2	2	2
1996	3	10	$10.76	24	12	18	2	10	46	9		4		5
1997	4	9	$15.60	23	0	15	0	12	42	8	1	2	1	6
1998	4	10	$14.68	22	5	12	2	14	52	9	1	3	2	3
1999	4	12	$9.97	23	3	21	1	18	61	16		3		8
2000	4	13	$9.71	23	4	16	1	18	50	6		1	4	2
2001	4	10	$13.68	27	9	12	12	20	63	3		4	1	3
2002	4	11	$14.51	24	4	22	2	23	65	2		4	4	4
2003*	4	13	$13.70	37	9	20	5	24	60	2		3	5	4

*Values estimated as of October 20, 2003.