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Cost-effectiveness Analysis

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Cost-effectiveness analysis refers to the consideration Of decision alternatives in which both their costs and consequences are taken into account in a systematic way. It is a decision-oriented tool, in that it is designed to ascertain which means of attaining particular educational goals are most efficient. For example, there are many alternative approaches for pursuing such goals as raising reading or mathematics

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achievement. These include the adoption of new materials or curriculum, teacher training, educational television, computer-assisted instruction, smaller class sizes, and so on. The cost-effective solution to this challenge is to ascertain the costs and effects on reading or mathematics achievement of each alternative and to choose that alternative which has the greatest impact on raising achievement scores for any given resource outlay.

Cost-effectiveness analysis is closely related to cost-benefit analysis in that both represent economic evaluations of alternative resource use and measure costs in the same way (see *Cost-Benefit Analysis*). However, cost-benefit analysis is used to address only those types of alternatives where the outcomes can be measured in terms of their monetary values. For example, educational alternatives that are designed to raise productivity and- income, such as vocational education, have outcomes that can be assessed in monetary terms and can be evaluated according to cost-benefit analysis. However, most educational alternatives are dedicated to improving achievement or some other educational outcome that cannot be easily converted into monetary terms. In these cases, one must limit the comparison of alternatives to those that have similar goals by comparing them through cost-effectiveness analysis.

The purpose of cost-effectiveness analysis in education is to ascertain which program or combination of programs can achieve particular objectives at the lowest cost. The underlying assumption is that different alternatives are associated with different costs and different educational results. By choosing those with the least cost for a given outcome, society can use its resources more effectively. Those resources that are saved through using more cost-effective approaches can be devoted to expanding programs or to other important educational and social endeavors.

Cost-effectiveness analysis was developed in the 1950s by the United States Department of Defense as a device for adjudicating among the demands of the various branches of the armed services for increasingly costly weapons systems with different levels of performance and overlapping missions (Hitch and McKean 1960). By the 1960s it had become widely used as a tool for analyzing the efficiency of alternative government programs outside of the military, although its applications to educational decisions have been much slower to develop. Indeed, in the early 1990s the use of the tool in considering educational resource allocation is restricted largely to the United States and has not emerged as a decision approach to resource allocation in other countries.

1. Measuring Cost-effectiveness

The basic technique has been to derive results for educational effectiveness of each alternative by using standard evaluation procedures or studies (Rossi and Freeman 1985) and to combine such information with cost data that are derived from the ingredients approach. The ingredients approach was developed to provide a systematic way for evaluators to estimate the costs of social interventions (Levin 1983). It has been applied not only to cost-effectiveness problems, but also to determining the costs of different educational programs for state and local planning (Hartman 1981).

1.1 Assessing Effectiveness

Before starting the cost analysis, it is necessary to know what the decision problem is, how to measure effectiveness, which alternatives are being considered and what their effects are. If a problem has risen on the policy agenda that requires a response, a careful understanding of the problem is crucial to addressing its solution (Levin 1983 pp. 34-35).

Once the problem has been formulated, it will be necessary to consider how to assess the effectiveness of alternatives. For this purpose, clear dimensions and measures of effectiveness will be needed. Table I shows examples of effectiveness measures that respond to particular program objectives.

Given the problem and criteria for assessing the effectiveness of proposed solutions, it is necessary to formulate alternative programs or interventions. The search for such interventions should be as wide-ranging and creative as possible. This procedure sets the stage for the evaluation of effectiveness of the alternatives, a process which is akin to the standard use of evaluation methods (e.g., Rossi and Freeman 1985). Estimates of effectiveness can be derived from previous evaluations or from tailored evaluations for the present purpose.

It is important to emphasize that the evaluation of effectiveness is separable from the evaluation of costs. Most standard evaluation designs for assessing the effectiveness of an intervention are also suitable for incorporation into cost-effectiveness studies. These can be found in the standard evaluation literature (see e.g., Cook and Campbell 1979, Rossi and Freeman 1985). The cost analysis is not typically found in the general evaluation literature and has been developed independently as a subspecialization (Levin 1983).

1.2 Cost Estimation

The costs of an intervention are defined as the value of the resources that are given up by society to effect the intervention. These are referred to as the ingredients of the intervention, and it is the social value of those ingredients that constitute its overall cost. At a later stage the distribution of these costs among the decision-making agency and other entities can be assessed. Accordingly, the method sets out systematically to identify and ascertain the value of the ingredients that are required for each alternative that is under consideration.



The ingredients approach to cost estimation entails three distinct phases: (a) identification of ingredients; (b) determination of the value or cost of the ingredients and the overall costs of an intervention; and (c) an analysis of the costs in an appropriate decision-oriented framework.

The first step is to ascertain which ingredients are required for an intervention (Levin 1983 Chap. 3). Most educational interventions are labor-intensive, so an initial concern is to account for the number and characteristics of personnel. It is important to stipulate whether personnel are part-time or full-time and the types of skills or qualifications that they need. Beyond this it is necessary to identify the facilities, equipment, materials, and other ingredients or resources which are required for the intervention.

Identification of ingredients requires a level of detail that is adequate to ensure that all resources are included and are described adequately to place cost values on them. For this reason, the search for ingredients must be systematic rather than casual.

The primary sources for such data are written reports, observations, and interviews. Written reports usually contain at least a brief history and description of the intervention. Other sources of information must be used to corroborate and supplement data on ingredients from evaluations and descriptive reports. If the intervention is present at a nearby site, it may be possible to visit and gather additional data on ingredients through observation. A third valuable source is that of interviews, where present or former personnel are asked to identify resources from among a number of different classifications. The three principal types of information-reports, observations, and interviews-can be used to assure the accuracy of the data by comparing the findings from each source and reconciling differences, the process of triangulation.

Once the ingredients have been identified and stipulated, it is necessary to ascertain their costs (Levin 1983 Chap. 4). In doing this, all ingredients are assumed to have a cost, including donated or volunteer' resources. That is, they have a cost to someone, even if the sponsoring agency did not pay for them in a particular situation. At a later stage the costs will be distributed among the constituencies who paid them, but at this stage the need is to ascertain the total costs of the intervention.

Ingredients can be divided into those that are purchased in reasonably competitive markets, and those that are obtained through other types of transactions. In general, the value of an ingredient for costing purposes is its market value. In the case of personnel, market value may be ascertained by determining what the costs would be for hiring a particular type .of person. Such costs must include not only salary, but also fringe benefits ' and other employment costs that are paid by the employer. Many of the other inputs can also be costed by using their market prices. These include the costs of equipment, materials, utilities, and so on. Clearly the cost of leased facilities can also be ascertained in this way.

Although the market prices of some ingredients such as personnel can often be obtained from accounting data for educational enterprises, such data are not reliable sources for ascertaining overall program costs. The accounting systems that are used by schools were designed for ensuring consistent reporting to state agencies rather than for providing accurate and consistent cost data on educational interventions. For example, they omit completely or understate the cost of volunteers and other donated resources. Capital improvements are charged to such budgets and accounts during the year of their purchase, even when the improvements have a life of 20-30 years. Normal cost accounting practices would ascertain the annual costs of such improvements by spreading them over their useful lives through an appropriate method (Levin 1983 pp. 67-71). Thus, data from accounting and budgetary reports must be used selectively and appropriately and cannot be relied upon for all ingredients.

Table I
Examples of effectiveness measures

| Program objective | Measure of effectiveness |
|---------------------------|---|
| Program completions | Number of students completing program |
| Reducing dropouts | Number of potential dropouts who graduate |
| Employment of graduates | Number of graduates placed in appropriate jobs |
| Student learning | Test scores in appropriate domains utilizing appropriate test instruments |
| Student satisfaction | Student assessment of program on appropriate instrument to measure satisfaction |
| Physical performance | Evaluation of student physical condition and physical skills |
| College placement | Number of students placed in colleges of particular types |
| Advance college placement | Number of courses and units received by students in advance placement, by subject |

There exist a variety of techniques for ascertaining the value of ingredients that are not purchased in competitive markets. For example, the method for ascertaining the value of volunteers and other contributed ingredients is to determine the market value of such resources if they had to be purchased. The value of facilities can be determined by estimating their lease value. The annual value of facilities and equipment can be estimated through a relatively



simple approach that takes account of depreciation and interest foregone by the remaining capital investment. Details for these techniques are found in Levin (1983 Chap. 4).

1.3 Combining into Cost-effectiveness

Once each of the ingredients is costed, these can be added to obtain a total cost for the intervention. The next stage entails the use of these costs in an analytic framework (Levin 1983 Chap. 5). The two most important concerns for cost summary and analysis are

- (a) the appropriate unit for expressing costs and (b) who pays the costs.

Clearly, the question of the appropriate unit for expressing costs depends upon how effectiveness is measured and the nature of the decision. Usually, educational effectiveness is measured in terms of achievement gains per student or some other per student measure. In that case, it is necessary to convert total costs to a per-student cost figure for comparing cost-effectiveness of alternative interventions. Cost-effectiveness ratios are usually based upon the average effects and costs per student. However, it is possible to do an analysis on total project or program costs and effects. In other cases it may be the additional or marginal costs versus additional or marginal effectiveness that is the subject of scrutiny. For example, one may want

to ascertain the number of additional students who will graduate from high school relative to the additional costs of alternative approaches for reducing dropouts.

A very different issue is who pays the costs. The overall cost-effectiveness ratio may be irrelevant to a decision-maker who pays only part of the costs for one intervention, but all of the costs for an alternative. For this reason, it is important to ascertain total costs of an intervention and to separate out those that are borne by the decision-maker in considering different alternatives. However, it should be remembered that since different decision-making units have different opportunities to obtain volunteers and contributed resources, it is inappropriate to assume any particular cost subsidy to the decision-maker. The basic estimate of costs that is used for all subsequent cost-analyses is the overall cost of the intervention. Subsequent analyses can distribute the costs among those who will bear them to ascertain the implication of that distribution for decisions.

The most common measure of cost-effectiveness is the cost-effectiveness ratio, namely, the effectiveness of an alternative divided by its cost. When this is done for each alternative, it is possible to see which of the alternatives yields the best outcomes per unit of cost. For example, one might wish to examine different alternatives for raising student achievement by comparing the cost per additional achievement gains. In principle, the alternative with the lowest cost per achievement gain would be the most desirable. However, it is important to know if differences in cost-effectiveness ratios are large or small. If the differences are small, it is probably wise to weigh more fully other criteria in making the decision such as the ease of implementation or previous experience of staff. If the differences in cost-effectiveness are large, it is important to place greater weight on the cost-effectiveness criteria while still considering other factors that were not considered in the analysis.

Finally, it is important to mention the issue of scale. In general, those alternatives with high fixed costs such as those with large investments in facilities and equipment will require a high enrollment or utilization to reach their best cost-effectiveness ratios. The reason for this is that fixed costs represented by a building or an educational television network of transmitters and receiving stations cannot be readily adjusted to demand and must be fully utilized to obtain the lowest level of cost per unit of output. In contrast, alternatives that are constituted largely of variable costs such as personnel will have costs that are less sensitive to the scale of output. Variable costs are derived from inputs or ingredients that can be readily increased or decreased.

Thus, a comparison of cost-effectiveness of alternatives that differ in terms of their intensities of fixed versus variable costs may produce very different results depending upon the scale of enrollment or output. Accordingly, estimates should be made among the alternatives for the specific levels of output that are pertinent rather than assuming a general pattern from cost estimation at only one level of scale.

2. Educational Applications

Cost-effectiveness studies have been carried out on teacher training (Tatto et al. 1991), teacher selection (Levin 1970), educational television and radio (Jamison et al. 1978), choice of a mathematics curriculum (Quinn et al. 1984), computer-assisted instruction (Levin et al. 1987) and also increasing the school day, reducing class size, and cross-age tutoring (Levin et al. 1987). Lockheed and Hanushek (1988) have provided a good summary of cost-effectiveness studies of educational radio and of textbook provision for several countries. Their comparisons among studies and interventions should be viewed cautiously given that the studies were done

independently for different years (with no standardization for changes in price levels or exchange rates) and are not necessarily based upon the same cost methodology.

2.1 Educational Television

The 1970s witnessed a great interest in educational television as a way of improving educational quality in developing countries, as well as expanding their



educational systems (Mayo et al. 1975, Jamison et al. 1978). In many developing, societies adequate numbers of trained teachers are unavailable-particularly in rural areas-or populations are so sparsely distributed that there are not adequate numbers of students in school attendance boundaries to justify minimum personnel requirements. Educational television has been viewed as an alternative for delivering instruction that might be less costly and that also might raise the quality of education. Studies were undertaken of educational television ' as a partial replacement for teachers in rural areas where examination test scores were used as a basis for effectiveness. Such studies found that the television was relatively cost-effective in comparison with traditional schools in that it produced comparable student achievement at lower cost (Mayo et al. 1975). However, these results depended heavily on certain assumptions which were highly controversial, illustrating the fact that cost-effectiveness comparisons must be reviewed carefully before using them for decision-making (Carnoy and Levin 1975).

2.2 Curriculum

Curriculum is an area that is very appropriate for cost-effectiveness analysis. In the quest for educational improvement, schools face numerous ways in which they can organize the pace, content, and method of instruction. Some are likely to be more effective than others, and there may also be substantial differences in resource requirements with respect to such ingredients as teacher time, materials, equipment, and so on. As with many other areas of education, the potential for using cost-effectiveness analysis has barely been tapped in the curriculum field.

An excellent cost-effectiveness study of fifth grade mathematics curriculum was carried out by Quinn et al. (1984). Their evaluation compared two approaches to teaching mathematics, a traditional curriculum and an alternative one. Using the ingredients method, the researchers found that the alternative mathematics program cost about 50 percent more than the traditional mathematics program, but the effectiveness of the alternative program was also higher. Depending upon how student achievement was measured, the alternative mathematics program was found to be from 60 percent to 300 percent more cost-effective -- cost per point of achievement score -- than the traditional program.

2.3 Teacher Training

A study of teacher training in Sri Lanka compared the cost-effectiveness of training in colleges of education and in teachers' colleges as well as through distance education (Tatto et al. 1991). Teacher performance and pupil achievement were used as measures of effectiveness. Teachers who had received distance education were almost as effective as those trained in colleges of education and teachers' college, but the costs of their training were a small fraction

of the costs of institutional training. In a country that has a shortage of teachers, it appears that expansion of qualified teachers could be done more efficiently using distance education.

2.4 General Comparisons of Reform Alternatives

An attempt was made to compare a variety of educational reforms that had been suggested for improving schools in the United States. In the early 1980s, such reports suggested a general reform agenda that included a large variety of alternatives. Levin et al. (1987) investigated four of these for which there were adequate effectiveness data as well as a basis for estimating costs. These four alternatives included computer-assisted instruction (CAI), a longer school -day, smaller class sizes, and peer tutoring. Each was associated With acceptable effectiveness studies that had assessed the effects of the reform on student achievement scores at the elementary level in both mathematics and reading.

More specifically, the CAI consisted of daily sessions of 10 minutes of drill and practice on a computer using an approach that has received wide adoption both in the United States and in other countries. The increase in the length of the school day comprised a total of one hour, divided equally between instruction in mathematics and reading. Changes in class size were evaluated for reductions from 35 to 30 students; 30 to 25 students; 25 to 20 students; and 35 to 20 students. Peer tutoring was evaluated for a program in which fifth and sixth grade students tutored second grade students for 15 minutes a day.

Costs were estimated by using the ingredients approach. They were summarized according to the cost per student for each subject. The least costly interventions were reductions in class size of five 9-ticdents and increasing the length of the school day. The most costly was peer tutoring because it requires adult coordinators. The costs of peer tutoring were about four times as great as reducing class size by five students or increasing instructional time by one half hour a day per subject and twice as great as the daily sessions of CAI.

In terms of effectiveness, peer tutoring showed the largest effects, nearly a year of achievement gain in mathematics and about one-half year in reading. The longer school day and reduction of class size by five students showed the smallest effects. CAI was associated with gains in the middle of the range of results.

Cost-effectiveness was determined by combining costs and effectiveness in terms of the estimated annual costs to obtain an additional month of student achievement per year of instruction. According to this



study, an additional month of mathematics achievement would cost about US\$200 a year with a longer school day, but only about US\$22 a year with peer tutoring. In fact, a longer school day was less than half as cost-effective in raising mathematics achievement as was CAI or reducing class size, despite the prominence of calls for longer school days in the national reports on educational reform. The most cost-effective approach, peer tutoring, required only one-ninth of the resources to obtain the same effect on mathematics achievement as increasing the school day.

To obtain an additional month of reading achievement would cost about twice as much for increasing the school day as using peer tutoring, with CAI almost as efficient as the latter. Reducing class size appears to be particularly inefficient with respect to raising reading

achievement. Although its effectiveness is very high, its cost is also high. These results provide useful information in comparing instructional strategies to raise achievement.

See also: Education Production Functions; Cost Analysis in Education; Cost-Benefit Analysis

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