The estimation of a shadow rate of return is a two-step process. In the first step, the marginal product of the target and control types of labor is arrived at by one method of shadow pricing, hence the name of this particular type of rate of return. In the second step, the above-estimated marginal products of labor are inserted in the ordinary rate of return formula for arriving at the *social* profitability of education. Shadow pricing is not suitable for estimating the private profitability of education as what enters in the latter is the observed market wages, regardless of their relationship to the true marginal product of labor.

Shadow rates of return can be used in an ex post sense to document existing misallocations of educational investments. Or they can be used in an ex ante sense for simulating the allocative effects of projected manpower requirements in the synthetic models of educational planning.

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Cost–Effectiveness Analysis in Education

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Cost–effectiveness analysis is a technique for measuring the relationship between the total inputs, or costs, of a project or activity, and its outputs or objectives. Both costs and effectiveness must be quantified, but it is not necessary to measure them in monetary terms. Cost–effectiveness analysis, therefore, must be distinguished from cost–benefit analysis, which attempts to measure both the costs and benefits of a project in financial terms by means of a rate of return. Cost–effectiveness analysis was developed for the evaluation of public policy in such fields as military defence, where the objectives are clearly definable and measurable, but not in money terms. It has more recently been used for project evaluation for other areas of public policy including health and education.

Cost–effectiveness analysis can take two different forms. In the first case a comparison is made between alternative ways of achieving the same objective, in order to identify that with the lowest cost. This is defined as the most cost–effective method of achieving the stated objective. In education this kind of cost–effectiveness analysis takes the form of comparisons between different institutions, different types of education, or different teaching methods. If the alternatives share the same objectives but have different costs, then it is possible to choose the most cost–effective method of achieving these objectives. Examples of this kind of cost–effectiveness analysis include comparisons of full-time and part-time education or correspondence education and conventional face-to-face teaching.

The other method of using cost–effectiveness analysis is to compare two or more schools or other institutions with similar levels of cost in order to discover which achieves the highest level of output or results. The most cost–effective institution is the one which maximizes the output achieved for a given level of cost. Because of the difficulty of identifying and measuring the output or objectives of education it is difficult to apply cost–effectiveness analysis to education as thoroughly and satisfactorily as to some other activities, and some analysts argue that it is impossible, and that cost–effectiveness analysis is an inappropriate technique for education. For example, one handbook of educational costing (Fielden and Pearson 1978) defines cost–effectiveness analysis and explains the two methods of applying it, but concludes

> Because educational outputs cannot be neatly measured this technique is invalid . . . constant or equal effectiveness is a myth. We recently undertook the evaluation of 30 projects which used computer-assisted learning in schools, universities, and training establishments. We found that in no case was cost–effectiveness analysis relevant to our work. (p. 18)

Nevertheless, despite the difficulty of defining and measuring the output of education, it is necessary to find some way of comparing the efficiency of different institutions, of choosing between alternative methods of achieving the same or similar objectives, and of identifying the most effective ways of using educational resources. Therefore there have been a number of attempts in different countries to apply the principles of cost–effectiveness analysis to education, even though the measures of output or effectiveness are often rather crude. Moreover, because the educational process and the individual institutions within the educational system have many different objectives, any attempt to apply cost–effectiveness analysis to education will yield different results, depending upon what measures of output or objectives are used. This article attempts to summarize the main attempts, but it must be remembered that these represent crude examples of the techniques of cost–effectiveness analysis, because of the problem of measuring outputs.

1. Measuring the Outputs of Education

The simplest way of measuring the output of education is in terms of the number of pupils who are educated in a school, or the number of graduates or qualified school leavers who leave an institution each year. Although this is a very poor measure of educational effectiveness, since it ignores the quality of education and it does not attempt to measure the knowledge or skills acquired by pupils or students, a comparison of per pupil costs in different schools which are attempting to achieve the same objectives may be the first step in applying cost–effectiveness analysis to education. The next step, however, is to attempt to measure the achievement of those objectives in terms of test scores, examination results, or some other quantifiable measure of educational achievement. The measure chosen will depend on the objectives of the programme. For example, if cost–effectiveness analysis is used to compare two different methods of language teaching, then effectiveness may be measured in terms of pupil scores on comprehension tests. On the other hand, a cost–effectiveness analysis of student aid programmes, the aim of which is to increase the participation of low-income students in higher education, might compare the effectiveness of loan and grant programmes in terms of the proportion of low-income students participating in the programme.

These two illustrations are simply intended to show that cost–effectiveness analysis can be applied to a variety of educational programmes, using many different measures of educational output or effectiveness. The measures are not necessarily concerned with the economic objectives of education, even though cost–effectiveness analysis is an economic technique.

In fact, attempts have been made to apply cost–effectiveness analysis to education by comparing different schools, universities, or other institutions and different teaching methods, with effectiveness measured in terms of scores in tests of cognitive and noncognitive achievement, the proportion of pupils or students who achieve a qualification or who enter higher education, and various other measures of educational attainment. The difficulty is that none of these adequately measures the objectives of education. However, this type of cost–effectiveness analysis can help in planning decisions because it identifies the cost implications of alternative policies.

The techniques of cost–effectiveness analysis were first developed in the United States, Canada, and Europe during the 1960s and an early review of the scope of cost–effectiveness analysis of education was provided by an Organisation for Economic Co-operation and Development conference in 1968 (OECD 1968), which provided a definition of the term cost–effectiveness analysis but also examined the distinctions between cost–effectiveness analysis and other techniques of programme appraisal, including cost–benefit analysis, programme budgeting, and systems analysis. This conference included descriptions of a number of attempts to devise measures of educational achievement in the United States, for example the Quality Measurement Project of New York State, a nationwide testing programme called Project Talent, and, one of the most widely reported, a study of regional and racial differences in the distribution of educational resources and pupil achievement known as the Coleman Report (Coleman et al. 1966).

This study of inputs and outputs in American schools is not, strictly speaking, an example of cost–effectiveness analysis, since its main purpose was to measure the extent of differences in costs and effectiveness of education in different regions and between different racial groups, but it provides the data which can be used for cost–effectiveness analysis in the form of costs and scores in achievement tests. For example, one study (Levin 1970) uses these data for a cost–effectiveness analysis of teacher selection, by combining information on pupil achievement in relation to teacher characteristics with data on the costs of alternative types of teacher training. However, the Coleman Report has attracted fierce controversy, particularly with regard to its negative conclusions about the effects of school inputs on levels of performance. Later these negative conclusions were echoed in another study (Jencks et al. 1972) which concluded, even more pessimistically

> Our research suggests . . . that the characteristics of a school's output depend largely on a single input, namely the characteristics of the entering children. Everything else— the school budget, its policies, the characteristics of the teachers—is either secondary or completely irrelevant.

The controversy surrounding these conclusions has given rise to a number of studies designed to investigate the influence of various school inputs, for example teacher experience and qualifications or expenditure on buildings and equipment, on measures of output and achievement.

2. The Relationship Between School Inputs and Outputs

There have been a number of recent reviews of research which have exhaustively examined various studies of the relationship between school inputs and outputs. Some of these studies actually use cost–effectiveness analysis while others do not use the technique, although they are designed to throw light on the links between costs and effectiveness. In the United States these studies have been reviewed in a study called *Do Teachers Make a Difference?* (US Department of Health, Education, and Welfare 1970) and another called *How Effective is Schooling?* (Averch et al. 1972). These questions emphasize the underlying uncertainty which developed, particularly in the United States, about the validity of cost–effectiveness studies, if school effectiveness is largely determined by factors outside the school. For example, one American review of research concluded that "Research to date has found little or

nothing in school resources that consistently and unambiguously makes a difference to student outcomes, such as achievement" (Nollen 1975).

There have also been a number of attempts to review research in other countries on the determinants of student achievement. One study of 17 developing countries (Alexander and Simmons 1975) found that expenditure variables were not important predictors of student achievement but identified some teacher characteristics which were linked with measures of achievement. The World Bank has extensively reviewed research into the relationship between teacher training and student achievement in less developed countries (Husén et al. 1978) and concluded that teacher characteristics do have a positive effect on student achievement and that teacher training does have an impact on effectiveness. Therefore although these studies do not use cost–effectiveness analysis they are highly relevant to questions about the validity of cost–effectiveness studies.

3. Cost–Effectiveness Comparisons Between Institutions

The majority of cost–effectiveness studies consist of comparisons between institutions which have the same objectives. The purpose of cost–effectiveness analysis in this case is to identify which school or university or which type of teaching, produces the output at lowest cost. Many studies have concentrated on the question of economies of scale, and have examined the relationship between size of school and per pupil cost, assuming that the level of output does not vary. Reviews of this research in the United States (Cohn 1975) and in the United Kingdom (Hough 1981) have shown that there is some evidence of economies of scale in primary schools, which means that the average cost per pupil is lower in larger schools than in smaller schools, but at the secondary level there is no clear and consistent relationship between school size and costs.

Cost–effectiveness comparisons have been attempted between different methods of teacher training, between full-time and part-time study, or between correspondence teaching and face-to-face instruction (Coombs and Hallak 1972). In all these cases difficulties arise in comparing the outputs of different institutions. For example, cost–effectiveness comparisons in the United Kingdom between the Open University and conventional universities (Wagner 1972, Laidlaw and Layard 1974) assume that the quality of graduates is the same, and concentrate on the question of cost differences. The use of cost–effectiveness analysis to evaluate

new technologies in education does, however, always raise the question of whether there are variations in output as well as input when new technologies are introduced (Layard and Oatey 1973). Because of this problem, cost–effectiveness analysis cannot provide completely satisfactory answers to the problem of choosing between alternatives but it can help to throw light on the relationship between inputs and output in education.

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Linear Programming Models

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Linear programming is a technique for the mathematical solution of a constrained optimization problem. As such, it has been used in educational planning by formulating an objective function to be maximized or minimized subject to a set of resource constraints. The objective function could be the contribution of edu-