Economic Evaluation of Health Care Interventions: 
A review of alternative methods

by

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1. Introduction

Inspection of international data\(^1\) on health status, as measured for instance by life expectancy, infant mortality and the child death rate would easily convince ourselves that health is distributed rather unequally in the world. It is evident that the latter is to be attributed to the fact that many nations are still in the process of development. Indeed, in developing countries resources are frequently scarce whence those that can be allocated to health development are often insufficient to secure a reasonably good health status. The truth is also that developing countries are forced to formulate objectives in the industrial and agricultural sphere that sometimes necessitate the withdrawal of resources from the health sector. However, history shows that economic growth will gradually alleviate constraints on resources, so that one can expect that over time more resources are likely to be spent in the health sector.

Economic evaluation in health care derives its importance from the fact that the resources allocated to the health sector are limited. The key problem the economist faces is to guide the allocation of those scarce resources so as to secure a maximum amount of health for society. He will thus have to help in deciding which health interventions to organize and for whom, and which type of resources will be used in organizing them.

Several economic evaluation techniques can be found in the economist's tool box. Among the most important are cost-benefit analysis (CBA), cost-effectiveness analysis (CEA), linear programming (LP), multi-attribute problem analysis (MPA) and econometric modeling (EM). The purpose of this paper is to describe these techniques as succinctly as possible, to point at their relative merits and to discuss certain dif-

\(^1\)See the Statistical appendix of Work Bank (1981).
ficulties in their application.

The common aim of these techniques is to contribute to decision makers' final choices. The outcome of alternative analyses should certainly not be considered as a substitute for human decisions. The techniques are merely instruments and their use serves as a reminder to decision makers that each decision has its implied economic cost and benefit.

Although the techniques to be discussed here are not new and are also used for guiding decisions in fields other than health care, a review is not without its use. For instance, an analysis by Caldwell and Dunlop (1979) on the use of techniques in 27 African and Latin American countries shows that only 2 and 8 countries make use of CBA and CEA respectively. The EM approach is used in only 6 countries. Rosenfield c.s. (1981) in their account of the research done in the Special Programme for Research in Tropical Diseases mention that one of the research objectives is to assess economic and social consequences. Yet, only the cost-effectiveness approach in analyzing disease control programmes and policies is emphasized. This illustrates that a continued study and gathering of information about alternative evaluation techniques is worthwhile.

It will be understood that the general setting implied in the paper is that of a developing country. Moreover when discussing the application of these techniques we will refer, wherever appropriate, to parasitic diseases, the subject of this conference. Note, however, that the various techniques can be applied equally well to health problems in developed countries.
2. Cost-Benefit analysis

2.1. Definition

We will define CBA as an approach to measure benefits and costs to society of a project or of a series of projects. The basic proposition is that benefits of a project should outweigh their costs if that project is to be accepted. If a choice has to be made between several alternative projects, the project with the greatest net benefit has to be chosen. Note that both benefits and costs are measured in terms of money.

2.2. Measurement of benefits and costs

(i) The most refined and correct way to measure a project's benefits is to find out what the maximum amount is that society is willing to pay for that project. The latter represents the gross welfare gain to society. Society's willingness to pay (WTP) is, in principle, equal to the sum of individuals' WTP. The concept of WTP will be further explained by means of the following example. Suppose that a particular health project provides a certain type of medical care to individuals. Neoclassical demand theory then defines a demand curve for each individual indicating the relationship between the price \( p_m \) and the desired quantity of medical care \( q_m \). This relationship is negative conveying that as \( p_m \) diminishes \( q_m \) rises; see Figure 1. Suppose now that government provides quantity OA. Demand theory says that, at the amount OA, the marginal utility of medical care is equal to \( AB^2 \). Moreover for all intramarginal units of medical care, the marginal utility is indicated by the

1 There are a number of useful books on CBA; see e.g. Dasgupta and Pierce (1978), Drummond (1980) and UNIDO (1972).

2 Stated more precisely, marginal utility of medical care is equal to \( AB \) up to a certain constant; this constant is equal to the marginal utility of income.
Figure 1 Demand for Medical care by an individual

For instance, at OE the marginal utility of medical care is EF, at OC the marginal utility is CD etc. It follows that the utility of OA is represented by the area under the demand curve between O and A, namely OGBA. Suppose now that the individual actually pays OHBA for the amount OA. The area GHB is then called consumer's surplus. In other words the individual's WTP is equal to the effective payment OHBA plus consumer's surplus GHB.

As was said above, society's WTP equals the sum of the individuals' WTP. This implies that society attaches the same value to each individual's WTP. It is a strong hypothesis that needs to be modified whenever government intends to introduce distributional considerations into the CBA.

\footnote{Strictly speaking this is only true if the individual's real income is kept constant as he moves along the demand curve. In that case the latter is called a compensated demand curve.}
(ii) In CBA the true cost of a particular project is the opportunity cost or the value of the benefits one sacrifices if resources are used in that particular project. In other words, costs are the foregone benefits of the next best project. Applied to health projects, this means that if one uses health personnel and drugs as inputs to a project, one has to inquire into the benefits of the use of these health resources in the next best health project. Sometimes the next best alternative is not defined. In that case one usually puts the opportunity cost equal to the foregone benefits of allocating the inputs into the economy at large. Usually, one makes use of marginal productivity schedules of the inputs to obtain a measure of the benefits these inputs entail. Note that these schedules indicate as well the maximum amount that society is willing to pay for these inputs.

(iii) The net welfare gain or net value of a project \( x \) (\( NV_x \)) is now equal to

\[
NV_x = WTP_x - WTP_y, \quad (2.1)
\]

where \( y \) refers to the next best alternative project. If the latter is not or cannot be defined

\[
NV_x = WTP_x - WTP^i_x, \quad (2.2)
\]

where \( WTP^i_x \) refers to society's WTP for the inputs used alternatively in the economy at large. If \( NV_x \) is positive, the project \( x \) may be undertaken.

(iv) Up to now, we have given some basic elements of CBA for projects that have benefits and costs in the current period. It is evident that projects may also entail future benefits and require future costs. It is here that some modification in the calculation of net value is required. First note that it is generally agreed upon that individuals prefer the present to the future. In other words \( 1 \text{ £} \) now and \( 1 \text{ £} \) one year hence will surely not have the same value. In that case one can
not simply add up benefits or costs that are related to different points in time. The market rate of interest in an economy can now be used as a first approximation of the social discount rate \( r \) that will enable us to add up a stream of net benefits. Indeed we know that 1 $ in year zero will be worth \( (1 + r) \) $ in year one, \( (1 + r)^2 \) $ in year two etc. Conversely, 1 $ in year one is worth \( \frac{1}{1+r} \) $ in year zero, 1 $ in year two is worth \( \left(\frac{1}{1+r}\right)^2 \) $ in year zero etc. The value in year zero of a $ received or paid in the future is called the present value of that dollar. Making use of the discount rate \( r \), we can calculate the net present value of a project (NPV) that lasts, say, for \( T \) years:

\[
NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t}
\]  

(2.3)

where \( B \) and \( C \) refer to benefits and costs respectively while \( t \) is the time index. As before \( C_t \) has to be understood as the benefits foregone in period \( t \). Note that if \( NPV > 0 \) society's welfare will increase whence the project can be adopted.

2.3. Problems in Benefit measurement

(i) When evaluating benefits of a health intervention one should pay considerable attention to its real output. Above, in order to explain the WTP approach, the example was given of a health project that provided a certain type of medical care. The latter can only be considered as an approximation of that project's output, since the real output is the improvement in health status. Measures of this health status improvement involve primarily mortality and morbidity rates. The correct way now to calculate the monetary benefit of a health status improvement, prescribed by economic theory, is to find out how much society is willing to pay for that improvement.

(ii) In some studies we find the application of the willingness-to-pay-approach. Let us cite that, by estimating indivi-
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duals' WTP for a reduction in the probability of dying, Acton (1975) is able to show that society is willing to pay a certain amount of money to reduce the occurrence of heart and circulatory diseases. Jones-Lee (1976) also uses a similar approach in order to estimate the value of safety. These studies are exceptions, however. There are several reasons for the lack of application of the WTP approach. First, when relying on the WTP approach, one trusts that the individual is able to make a correct assessment of the expected health status improvement. Frequently policy-makers and planners question this so-called consumer sovereignty by positing that the individual will often misjudge the correct health status changes. The latter would be an argument against WTP estimation by means of a questionnaire. Secondly, in many developing countries certain health interventions are introduced for the first time whence one cannot make use of empirically observed demand and behavior to calculate the WTP. Thirdly, if individuals' WTP can be solicited, one may voice objection against the fact that the answers are linked to the existing income distribution. If the WTP are subsequently added in the benefit calculation, one attaches implicitly more importance to high income receivers with a possibly high WTP than to low income receivers with a weak WTP. Fourthly, in most health interventions against parasitic diseases the major benefit consists of averted death. In that case it would be awkward to ask people what they are willing to pay to avert a certain death, since the value of a life to a person is likely to be almost infinitely high if he is confronted with the choice between life and death\(^1\).

(iii) A major alternative to the WTP approach is to consider the net benefits of a project as consisting of net production gained and

\(^1\)See especially Broome (1978) on this point.
the cost savings as a result of that project. Net production gained can be the consequence of a decrease in mortality, morbidity (loss of working time) and debility (loss of productive capacity while at work). It is usually estimated by using earnings data for the individuals whose health has improved. The cost savings can also be regarded as a benefit because the funds freed by a project can be used in other benefit entailing health projects. Several problems may arise while using this alternative, however. First, it is not sure that one can simply use the wage rate of workers as a measure of the gain in production. If wages are used that happen to be set artificially above workers' marginal productivity, the gross value of a project will be overestimated. One therefore has to use a shadow wage rate, viz. a wage rate that correctly reflects workers' productivity. Secondly, suppose that there are women, children, handicapped and old aged among the beneficiaries of a project. How is their contribution to society's product to be measured? Benefits of health improvements for women can be calculated by making use of the wages women earn or may earn in the labor market. In order to measure the benefits of health improvements for children one has to calculate their contribution to society's output in the future. Health care for the old aged or handicapped may have no immediate economic benefit. Yet, society may in any case attach a certain value to the health care for the so-called unproductive. One comes to the conclusion that in such cases one should ideally use the WTP approach! Thirdly, if cost savings are actually used in the benefit calculation, there is a chance that total benefits will be underestimated: indeed the new health interventions financed by those freed funds may enhance benefits that may exceed the interventions' financial cost. Fourthly, this alternative approach is sometimes attacked for its lack of consideration for intangible benefits such as reduction of pain and misery. One forgets, however, that the eventual omission of intangible benefits is the result of not using the WTP approach!

(iv) Summarized we must recognize that the WTP approach provides

\[1 \text{The distinction between mortality, morbidity and debility is taken from Mushkin (1962).}\]
the most elegant and theoretically sound way to calculate health benefits in monetary terms. Yet given the problems mentioned above, one can understand why health researchers prefer alternative methods. In any event, it would certainly not be wise to automatically discard the WTP approach. In addition, one must always bear in mind that gain of production and cost savings merely constitute a minimum approximation to the true welfare benefits.

2.4. Problems in cost measurement

(i) We have already emphasized the necessity to view costs as the maximum alternative benefits foregone. If a project is not competing in particular with another project, one needs to calculate the benefits foregone for the economy at large. Society's willingness to pay for an input will indicate the benefit generated by that input. In the case of labor inputs (e.g. health workers, nurses, physicians), one generally approximates WTP by the earnings of the relevant skill category. However the latter will only reflect true social productivity if labor markets are competitive and if the project entails small movements of labor from one sector of the economy to the others. First, competitiveness of labor markets signifies that all labor can be hired at the prevailing market wage and that the users of labor do not exercise any monopoly buying power in the labor market. These conditions lead to an equality between the market wage rate and the value of marginal productivity\(^1\), whence the former can be used to measure the loss to society of withdrawing a unit of labor from the economy at large. Secondly, only if the project is small can the market wage rate be used for all units of labor. Indeed, larger projects entail such a withdrawal of resources that marginal productivity is not likely to remain constant. In that case

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\(^1\) See UNIDO (1972, ch. 5) on this issue.
one needs to know the demand curve\(^1\) for labor in order to measure the total production loss caused by the withdrawn resources.

Note further that when non-human inputs (such as drugs, hospital buildings etc.) are involved in a project, one should also proceed by estimating society's WTP for these inputs. When input markets are non-competitive, one needs to estimate the shadow prices of the inputs, viz. the prices that correctly express the inputs' productivity.

(ii) A special issue arises when inputs have to be imported. These cause a decrease in the available foreign exchange for other uses. One then needs to estimate the willingness to pay for this foreign exchange. Only in competitive foreign exchange markets will the official exchange rate reflect this willingness to pay. In the case of restrictions in the foreign exchange market, the willingness to pay is usually higher than the official exchange rate. Note also that when imported inputs are financed by grants, the opportunity cost will be zero if there is no reduction of grants to other feasible projects. When projects are financed by loans, the repayments do of course entail a cost of foreign exchange.

2.5. Some refinements in Cost-Benefit Analysis

2.5.1. The appropriate discount rate

(i) Above in section 2:2, we stated that the market rate of interest is only a first approximation to the social discount rate. In some cases, the market rate of interest is considered to be inappropriate when it does not reflect individuals' preferences for capital accumulation in society\(^2\). In other words, the market rate of interest may understate society's interest in the welfare of

\(^1\)At each quantity of labor, the corresponding point on the demand for labor curve reflects marginal productivity.

\(^2\)See on this point UNIDO (1972, pp. 156-160).
future generations when it merely reflects individual preferences regarding optimal individual allocation of income. The solution to this problem is to estimate society's willingness to trade off present and future benefits. In general, this will produce a social discount rate inferior to the market rate of interest. Yet, the problem of estimation remains and one often argues against this procedure because of its arbitrariness.

(ii) Frequently the use is advocated of the opportunity cost of public projects as the appropriate social discount rate. The reasoning is the following. If funds are not invested in the public sector, it is very likely that they are invested in the private sector. There they earn a rate of return which is selected as the social discount rate. The decision rule for accepting a public project is then the following: only if the net present value is positive, should the project be adopted since the public project will in that case give a higher amount of net welfare to society than an alternative private project.

This approach has also its disadvantages. First, it is possible that public funds have no alternative use in the private sector because of slack in the economy. Secondly, it is not simple to pinpoint a single private rate of return since the latter may depend upon the type of industry with which the alternative private projects are associated.

(iii) In view of the uncertainty regarding the optimal selection of the social discount rate, the UNIDO Guidelines propose instead to consider the latter as an unknown to project evaluation. What they suggest is to calculate the internal rate of return of a project or of alternative projects. This rate of return is the discount rate for which the net present value of a project is zero. According to the Guidelines the comparison of alternative internal rates of return will force decision-makers to consider the consequences of the final choice made. They further state that 'Unlike more conventional use of the internal rate of return, there is no objectively
determined bench mark with which each project can be compared. The only relevant bench mark is the intention of responsible policy makers, which, after sufficient exercise, may be quantifiable into a consistent cut-off rate of return that would fulfil the condition required of a social discount rate.\footnote{UNIDO (1972, p. 172)}

It is recommendable to take a pragmatic attitude regarding the selection of a discount rate. It is probably better not to exclude any method of social discount rate selection. The project analysts should be left some freedom here. Yet a prerequisite for accepting the cost-benefit analysis has to be that project decision makers are to be fully aware of the implied values and the consequences of their selected discount rate.

2.5.2. Distributional objectives

(i) When net benefits of individuals resulting from a project are added, it is implied that each unit of benefit has the same welfare significance. In other words, the net benefit of 1 $ to a rich individual has the same value to society as the net benefit of 1 $ to a poorer individual.
It is possible that society wants to incorporate distributional objectives into the CBA. Suppose that in health projects one wants to attach a greater welfare weight to the benefits receivers by lower income receivers than by higher income receivers. This does not necessarily mean that one considers the health status of the former to be more important than that of the latter. It generally implies that improvements in health status for the poor are valued more than those for the richer categories.

(ii) Various possibilities\(^1\) exist to estimate the welfare weights. First, one could derive values for the welfare weights that are implicit in past government decisions concerning the distribution of benefits. Another method consists of using as weights the inverse of the marginal income tax rate that would be applicable to various income groups; the latter would mean that one weighs the net gains to lower-income groups more heavily than the net gains of the higher-income groups. Lastly, one could use the ratio of the national income per capita to the average income of that particular income group as a weight for the net benefits of an income group. The latter will also tilt welfare weights in favor of the lower-income group.

2.5.3. Risky projects

It has to be granted that projects often entail benefits and costs whose magnitude depends upon the occurrence of certain events. We can then say that these benefits and costs are risky. In health interventions, events have to be understood as different states of the world that produce different health outcomes. For instance, an anti-parasitic disease campaign may lead to different degrees of effectiveness each associated with some probability.

\(^1\)See Dasgupta & Pierce (1978, pp. 61-69).
If one knows the probability distribution of the states of the world, one can adjust the decision rule. Suppose that we consider a health intervention with 10 alternative sequences of events with the corresponding net gains. Each sequence of events is associated with a particular probability $p_i$. Formula (2.3.) can be adjusted then in order to give the expected net present value (ENPV):

$$\text{ENPV} = \sum_{i=1}^{10} p_i \sum_{t=0}^{T} \frac{B_i^t - C_i^t}{(1+r)^t}$$ (2.4.),

where the superscript $i$ refers to the sequence of events $i$.

2.5.4. Externalities

In CBA one is primarily interested in the net gains for the target population of a project. However, in many cases a project has also an impact on individuals (producers and consumers) outside the project. These impacts are called external effects. For instance, a health project comprising the eradication of the simulium fly (the vector of river blindness) may make certain fertile but abandoned lands (due to the illness) fully accessible again to the whole population. This health project would then not only generate benefits in terms of health status improvement but also in terms of additional production possibilities for society as a whole. If the WTP approach of benefit evaluations is used, there is a chance that if people are well informed, these indirect benefits are reflected by the willingness to pay. If the alternative approach is used, one has to check carefully whether such indirect but important benefits are not overlooked.

Another example of indirect benefits is the following. Suppose that a health intervention program consists of improving the nutritional status of children. The method adopted to enhance
children's nutrition is to give nutrition education to mothers. The direct benefits would consist of children's health benefits. Yet indirect benefits would consist of improved health of the mothers themselves and of their husbands!

One may hesitate to tackle the measurements of externalities because the indirect benefits are numerous. In other words the chain of indirect effects may never end. The objection is understandable. In that case one may need a systems approach to evaluation because the scheme of interactions becomes too complicated to be handled well by CBA.

2.6. Practical decision rules in CBA

First, if one has to decide whether to accept a single project, one can easily apply the NPV\(^1\) rule. Secondly, if one has to select a single project among a range of alternative projects one has to choose the project with the highest NPV. Thirdly, suppose that one has to decide about the size of a project; for instance, the issue could be how many health workers to allocate to a project. In that case the optimal size will be given at that number of health workers where the marginal benefit of a health worker is equal to its marginal cost. Note that this rule is equivalent to the second one if alternative projects are characterized by an alternative input of health workers. Fourthly, which decision rule do we have to apply when we have to allocate a fixed number of inputs between subprogrammes of a health project? For example, suppose that a health project involves the operation of a hospital and a rural health center, and that a fixed number of health workers has to be allocated between those two institutions. The decision rule is that the allocation of health workers is optimal only if the net marginal benefits of their working in the hospital (MB\(_h\)) and the net marginal benefits (MB\(_r\))

\(^1\)This is meant to include the ENPV rule.
of their working in the rural health center are equalized. Indeed as long as \( MB_r \) exceeds \( MB_h \) it pays to shift a health worker from the hospital to the rural center. Fifthly, suppose that one has to decide about a combination of projects when there is a budget constraint. In that case one chooses that combination that maximizes total net present value.

3. Cost-effectiveness analysis

3.1. Definition

Cost-effectiveness analysis (CEA) is a method that enables the health researcher to determine the cheapest strategy to meet a well defined health target, or to determine the optimal strategy to meet an objective when given a fixed budget. CEA differs from CBA in the sense that in CEA a specific target or a particular type of objective is already given. In other words in CEA of health projects with a certain target or objective, one does not have to ask oneself whether there are eventually other targets or objectives with a higher social value! Note in addition that frequently targets or objectives are not measured in monetary terms, as in CBA, but in terms of health indicators.

In a way then CEA seems also easier to use because one does not have to be directly concerned with social and ethical values of eventual alternatives. The latter is true, but one has to realize that any decision concerning targets or objectives is implicitly loaded with value judgments. In other words, CEA is not concerned with value judgments because certain value judgments are already implicitly accepted.

An example of a problem that might be treated with CEA is the reduction of the infant mortality rate from 139 \(^\circ\) to 60 \(^\circ\) within a period of 5 years. There are now various options that
can guarantee that this target will be met. The CEA technique will detect which option has least cost. Alternatively CEA might treat the problem of selecting a particular strategy that will minimize infant mortality rate with a given health care budget.

3.2. Elements of Cost-effectiveness analysis

3.2.1. Optimal choice given a certain budget

(i) In order to make clear what CEA does, we will take the example of efforts to decrease infant death in a rural developing area. Imagine that various options to provide appropriate health services are technically possible: the construction of two stationary baby clinics, the construction of one stationary baby clinic in a centrally located village, a mobile unit that serves every village twice a month and two mobile health units that serve every village once a week. Each of these options involves a certain global cost \( C_i \), the subscript \( i \) referring to option \( i \) \((i=1,\ldots, 4)\). The efficiency of these options is measured by their impact on the infant mortality rate; each impact is denoted as \( E_i \), \( i \) referring to the option. We can then construct an impact ratio \( \frac{E_i}{C_i} \) or the figure of merit as it is called by Seiler (1979, p. 74).

(ii) Let us now depict the choice problem in Figure 2. Assume first that one has to satisfy a certain budget constraint, namely \( C_i \leq B_1 \) for all \( i \). With a fixed budget \( B_1 \), only two options satisfy the budget constraint. CEA will choose option 3 as the optimal one since it maximizes the objective. The choice rule therefore consists of maximizing the figure of merit, or to choose that option whose corresponding straight line (OO\(_2\) or OO\(_3\)) has the largest slope.

Imagine now that the budget is enlarged from \( B_1 \) to \( B_2 \). The optimal choice will then be option 4. Remark that the ratio \( \frac{E_4}{C_4} \)
is lower than \( \frac{E_3}{C_3} \). Maximization of the figure of merit is in this case inappropriate. The choice rule in the event of flexible budgets merely instructs to maximize the efficiency indicator \( E_i \).

**Figure 2**
The choice of a most cost-effective option given a budget

![Graph showing decrease in infant mortality and options]

**Note:** The symbols O and B refer to option and budget respectively.
(iii) Some additional recommendations are in order. First, as is clear from the analysis above, one does not necessarily have to exhaust the budget. Secondly, one has to be as complete as possible in the formulation of all feasible options; in this way one will indeed secure the choice of the least-cost alternative. Thirdly, all costs have to be counted when computing the cost for each option. In our example above we have to include the cost of health personnel, the construction cost of the health station, cost of the vehicles, maintenance cost of the health station or mobile units. In the case of the health station it is recommended to include the money cost incurred by patients who have to travel to the clinic and who may thereby loss productive time. Fourthly, in a number of situations, the options are not strictly separable but can be combined. Take, for instance, the case of staffing a rural health clinic: one has the choice between various combinations of inputs such as drugs, physicians and paramedical manpower that can provide an improvement in health status. It is evident, however, that if we want to select the most-effective combination, we need to have a measure of the health output and the corresponding cost of the various combinations.

3.2.2. Optimal choice given a certain target

Here one has to consider the various options that can guarantee that a fixed target can be met. The objective is then to minimize the cost of reaching that target. After computing the total cost of each option, the decision rule dictates to choose that option with the largest figure of merit. Let us illustrate this with the following simple example. In a certain rural village one wants to avert a certain number of deaths per year by organizing an anti-malaria campaign. Let us suppose that there are three techniques or options to eradicate malaria. They are associated with costs $C_1$, $C_2$ and $C_3$ respectively, whereby $C_3 > C_2 > C_1$. It is clear now that, given the number of deaths to be averted, the most cost-effective option would be option 1; the associated figure of merit is indeed highest. The choice can also be depicted in Figure 3.
4. Linear programming
4.1. Definition

Programming is defined by Baumol (1977, p. 76) as 'the mathematical method for the analysis and computation of optimal decisions which do not violate the limitations imposed by inequality side conditions'. One speaks about linear programming (LP) if, in the objective function and constraints, the variables are multiplied by constants and added together. The common element with the evaluation methods discussed up to now is that one also maximizes or minimizes some objective by means of an optimal allocation of resources or inputs. A specific characteristic is that in-LP one is using inequality constraints, implying that maximum available resources do not have to be exhausted.
4.2. Formulation of a LP problem

The general formulation\(^1\) of a LP problem is:

Optimize (maximize or minimize) \[ \sum_{j=1}^{n} w_j x_j \] \hspace{1cm} (4.1)

subject to \[ \sum_{j=1}^{n} a_{ji} x_j (\leq, \geq, =) r_i \] \hspace{1cm} i=1, \ldots, m \hspace{1cm} (4.2)

and \[ x_j \geq 0 \] \hspace{1cm} j=1, \ldots, n \hspace{1cm} (4.3)

When the LP problem is a maximization problem, (4.1) is called the maximand; \(x_j\) is decision variable \(j\) whereas \(w_j\) is the coefficient of \(x_j\) that represents the contribution per unit of \(x_j\) to the maximand. Expression (4.2) refers to the structural constraints in which the coefficients \(a_{ji}\) are constants. Note that each structural constraint is associated with only one sign in \((\leq, \geq, =)\). Finally, (4.3) refers to the nonnegativity constraints.

If the LP problem is a minimization problem, (4.1) can be referred to as the minimand. The coefficient \(w_j\) is then the contribution per unit of \(x_j\) to the minimand. As before (4.2) and (4.3) are the structural constraints and nonnegativity constraints respectively. Note finally that both the maximand and the minimand can be called objective functions.

LP may be very useful in deciding upon the optimal allocation of resources in health projects. For instance, in the maximization problem, the \(x\) variables may refer to health inputs such as drugs, vaccinations, nurses, labor time of health workers, midwives, nurses, physicians etc. The \(w_j\) weights could be expressed, for instance, in terms of lives saved. The restrictions could contain, say, an overall budget constraint for the health project and separate restrictions on health inputs. The example just given may be easily converted into a minimization problem. The problem to be solved could then be to minimize the cost of the health inputs sub-

\(^1\)See Budnick, Mojena and Vollman (1977, pp. 108-109)
ject to the minimum achievement of certain health goals such as a minimum number of lives to be saved.

4.3. Graphical solutions of LP problems with two choice variables

(i) The solution of problems with two choice variables can easily be depicted on a graph. Let us treat here the example (with hypothetical figures) of allocating two types of insecticides in an anti-malaria campaign, given a budget constraint in order to obtain the maximum number of lives saved. The example is as follows:

Maximize $200x_1 + 100x_2$ \hspace{1cm} (4.4)
subject to $15x_1 + 10x_2 \leq 180$ \hspace{1cm} (4.5)
$x_1 \leq 4$ \hspace{1cm} (4.6)
x_2 \leq 14 \hspace{1cm} (4.7)
x_1 \geq 0 \hspace{1cm} x_2 \geq 0 \hspace{1cm} (4.8)

In (4.4) the variables $x_1$ and $x_2$ denote two different types of insecticide (in tons). The coefficients in the maximand represent estimated number of lives saved per ton of insecticide. Restriction (4.5) is the budget constraint in which the coefficients represent the prices of the two insecticides. Restrictions (4.6) and (4.7) refer to restrictions on the maximum available quantity of insecticide for the antimalaria campaign, whereas (4.8) represents the nonnegativity constraints.

The solution is presented in Figure 4. The area contoured by bold lines is called the feasible region. The latter contains all feasible solutions to the problem. The dashed lines represent the 'saved lives' isoquants.\(^1\) The maximum amount of lives saved is achieved at $S$, one of the corners of the feasible region. We see that the optimal solution implies that all available tons of $x_1$ and 12 tons of $x_2$ are utilised.

\(^1\)In an isoquant, the various alternative combinations of inputs are depicted that secure an identical 'output'.

(ii) Let us now turn to the graphical solution to a minimization problem with two choice variables. Suppose the problem at hand is that of minimizing the money cost of an anti-malaria campaign using two types of insecticides. The requirements are that a minimum number of lives has to be saved and that a minimum number of mosquitoes has to be exterminated. This imaginary program is as follows:

\[
\text{Minimize } 15x_1 + 10x_2 \quad (4.9)
\]

Subject to
\[
200x_1 + 100x_2 \geq 1600 \quad (4.10)
\]
\[
1000x_1 + 200x_2 \geq 14000 \quad (4.11)
\]

Requirement (4.10) implies that a minimum of 1600 lives have to be saved whereas requirement (4.11) imposes the eradication of at least 14000 mosquitoes. In Figure 5, the graphical solution is presented. The set of feasible solutions is now to be found to the right of the bold lines. In the present case, the dashed lines refer to isocost curves. It can be seen that the minimum cost is obtained at corner T; both requirements are exactly satisfied.

4.4. Shadow prices

The solution of the maximization problem above implied that the constraint on insecticide \(x_1\) was binding, whereas the constraint on \(x_2\) was nonbinding, meaning that demand for \(x_1\) is strictly less than its available supply. Suppose now that we relax the constraint on \(x_1\), namely \(x_1 \leq 5\) instead of \(x_1 \leq 4\). In Figure 4, the constraint moves upward, entailing an increased value of the objective, represented by point \(Z\). At the latter point, the 'saved lives' isoquant will be located farther to the right than the isoquant associated with \(S\). The lives saved at \(S\) amount to 2000 whereas 2040 lives are saved at \(Z\). The increase in lives saved, namely 40, is called the shadow price of \(x_1\). In other words, the shadow price is the change in the objective due to a change in the quantity of an input whose constraint is binding.

\[\text{An isocost curve represents various combinations of inputs that lead to an identical financial cost.}\]
In the case of an input with a nonbinding constraint, the shadow price is zero. The optimal solution of the LP problem is then independent of the total available supply of that input, since its supply exceeds its demand at the optimum.

Knowledge of shadow prices is particularly useful if we want to have an idea of the marginal contribution of inputs to the objective. Alternatively, shadow prices give us information about the opportunity we loose in not being able to use additional inputs due to constraints.¹

4.5. Problems in using LP for health projects²

Firstly, problems in health care evaluations are likely to be much more complicated than the simple examples given above; many constraints may be involved. For instance in the case of anti-malaria campaigns, there may also be constraints on the amount of different categories of health personnel and different types of vehicles. The means used in an anti-parasite campaign also involve various methods besides insecticides, viz. malaria vaccines, biological and genetical control of the vector and environmental management. In that case solution techniques such as the simplex method³ are used to handle more complicated LP problems. The reader has noticed that optimal solutions occur at a corner of the feasible region. The simplex method searches for the corner that gives the objective's optimal value by calculating the values of the objective function at the corners of the feasible region; if a certain corner happens to have two adjacent corners with an inferior objective value, that particular corner is selected as the best point.

¹Note that, the notion of shadow prices is closely linked to that of duality in linear programming. See further Baumol (1977, ch. 6).

²See also Dunlop (1975).

³See Baumol (1977, ch. 5) for a thorough description of this method.
Secondly, it may be possible that either the objective function or the constraints, or both, are nonlinear, so that the application of non-linear programming may become necessary. Furthermore, one of the assumptions of LP is that all activities assume continuous values. It frequently happens that choices require integer solutions; for instance 10 instead of 10.3 health workers, 2 instead of 2.2 vehicles etc. In the latter case, one may need integer programming.\(^1\)

Thirdly, it is evident that one needs careful information about prices and the way constraints are to be formulated. Moreover, one has to agree upon the objective. In some cases, the health researcher would want to take into account multiple objectives rather than a single objective. The latter problem can be solved by means of goal programming which is a variant of LP.\(^2\)

Despite the warnings concerning the use of linear programming, it has to be recognized that programming in general is a valuable technique for tackling choice problems in health care interventions. The requirement is, once again, that one should have correct information about the specification of constraints and that one should agree upon the formulation of the objective(s). Nowadays, various computer algorithms are available, even for micro-computers, which eventually will allow the health researcher to use programming techniques successfully.

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\(^1\) In certain cases, the integer problem may still be solved by an adjusted LP approach. See Greenberg (1978, ch. 3).

\(^2\) See Budnick, Mojena and Vollman (1977, pp. 351-366).
5. Multiattribute problem analysis

5.1. Definition

Health interventions frequently have so many characteristics or attributes that they are difficult to combine into one benefit measure, as is done by the techniques discussed previously. It may also be that the health researcher is reluctant to melt into one measure the information content of different attributes. Multiattribute problem analysis (MPA) now consists of procedures to decide about an optimal combination of attributes, thereby refraining from weighting the attributes and combining them into a single measure.

MPA can, for instance, be applied to the following problem: suppose one has to decide between a number of alternative health projects to combat tropical diseases. Each project has a number of attributes such as the reduction of infant mortality, the reduction of adult mortality, the reduction of morbidity, the number of working days gained, the reduction of pain and the project's money cost. MPA will throughout the analysis respect the six dimensions of each project. This clearly contrasts with CBA whereby one expresses the various costs and benefits in one monetary unit. In the present example, one could say that MPA has the special advantage of taking account explicitly of such attributes as pain suffered by the ill; it may indeed be rather difficult to compute the monetary equivalent of a reduction in pain. One might also find it tedious to evaluate the monetary gains of decreased mortality and morbidity and therefore turn to MPA.

MPA is different from CEA as well. Namely, in cost-effectiveness studies, one minimizes the cost of a given target, or, one maximizes an objective given a certain budget. In other words, compared to MPA, the choice problem in CEA remains essentially undimensional.
5.2. Objectives and attributes of health interventions

In the literature on decisions with multiple objectives\(^1\), one makes a distinction between an overall objective, lower-level objectives and attributes. The first type of objective refers to an area of concern\(^1\). For instance a health intervention project may have as area of concern the improvement of the health status of the covered population. But this general objective gives too little information on the specific aims of a health intervention. Lower-level objectives have therefore to be specified such as 'reduce death' and 'reduce adult male morbidity'. Each of these lower-level objectives has to be associated now with attributes that will indicate to what extent alternative health interventions meet the objectives. For example, the death reduction objective can be associated with the attributes infant mortality rate and adult mortality rate, whereas the morbidity reduction objective can, for instance, be linked to the attribute 'number of work-days gained' through the health intervention. Remark that the cost of a project may also be incorporated in the MPA as an attribute! This means essentially that one is no longer obliged to work with hard budget constraints as in CEA and, frequently, in CBA.

As alluded to in section 5.1 a physical feeling like pain may be an important attribute of a project. However, it may be difficult to measure pain, unless one is willing to construct a pain index, of course. A reasonable alternative may be to look for a proxy attribute. For instance, the number of work-days gained could be regarded as a first (rough) approximation of the reduced amount of pain in the sense that a work-day gained represents a (painful) day less in bed.

\(^1\)Keeney and Raiffa (1976, p. 32).
5.3. Choice procedures

5.3.1. Dominance

Suppose we have \( n \) types of health interventions \( H_i \) (\( i = 1, \ldots, n \)) with attributes \( a_{ij} \) (\( j = 1, \ldots, h \)), where the subscript \( i \) refers to the type of intervention and superscript \( j \) to the type of attribute. Let us assume that the value to society of the health interventions depends positively on \( a_{ij} \). We can now state that, for instance, \( H_1 \) dominates \( H_2 \) when

\[
 a_{1j} > a_{2j} \quad \text{for all } j \quad (5.1) \\
 a_{1j} > a_{2j} \quad \text{for some } j \quad (5.2)
\]

We can continue to compare the different alternatives on a pairwise basis, until one obtains a set of nondominated alternatives. The dominance technique therefore reduces the range of alternatives among which a choice has to be made. The weakness of this approach, however, is that no advice is given about the optimal choice to be made. Yet, a decision-maker may like this approach because he remains confronted with the different attributes up to the point of final decision.

As an example, let us take 5 possible health interventions with 4 attributes, namely reduction of the infant mortality rate (aged 0-1), reduction of the child mortality rate (aged 1-16), reduction of the adult mortality rate (aged 16+) and number of workdays gained per year per man. Below, hypothetical figures are presented in Table 1. We see that both health interventions 5 and 1 dominate alternatives 2, 3 and 4. It can also be seen that intervention 5 does not dominate intervention 1 because the former performs worse in terms of the second and fourth attribute. It is

\[\text{See also Keeney and Raiffa/1976, ch. 3/}.\]
evident that the final choice between alternatives 1 and 5 remains to be made. That choice will depend upon how the decision-maker ultimately values the different attributes.

Table 1. Search for dominant alternatives

<table>
<thead>
<tr>
<th>Health intervention</th>
<th>Reduction in infant mortality in %</th>
<th>Reduction in child mortality in %</th>
<th>Reduction in adult mortality in %</th>
<th>Number of workdays gained per year, per man</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25</td>
<td>12</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>5</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>10</td>
<td>12</td>
<td>14</td>
</tr>
</tbody>
</table>

* non-dominated alternatives

5.3.2. Lexicographic ordering

In this procedure the attributes are ranked according to importance. The procedure then determines that health intervention i is best if

\[ a_i^1 > a_k^1 \text{ for all } k (k=1, \ldots, n) \]  \hspace{1cm} (5.3)

where \( i \neq k \)

It is possible that all health interventions do equally well on the first attribute. One then has to turn to the secondly ranked attribute and apply the rule:

select i if \( a_i^2 > a_k^2 \text{ for all } k (k \neq i) \) \hspace{1cm} (5.4)

Again, if the alternatives are performing equally well on the second attribute, one has to turn to the thirdly ranked attribute etc.

Lexicographic ordering is very simple to use and may therefore sound attractive to policy-makers. However, one has to rea-
lize in this case that one basically only looks at one attribute and neglects the performance on all other attributes! To illustrate the latter, we refer to the example of the previous section. Suppose the reduction in child mortality is the firstly ranked attribute. Intervention 1 will therefore be selected. This implies then that one neglects the better performance of intervention 5 in terms of the first and third attributes!

5.3.3. Substitution in value between attributes and the computation of equivalent alternatives

(i) Above in 5.3.2. the preference structure was very elementary. In this section, a procedure is analyzed whereby all attributes are elements of the preference structure. To make this procedure as clear as possible, we will use the example given above in 5.3.1. (see Table 1). The analysis there resulted in two non-dominated alternatives. Without more information about the decision-makers' preferences, these are hard to compare, however. The way to proceed further is to look for equivalent alternatives whereby all attributes safe one are equalized. Thus at the end only one attribute will (or is likely to) differ so that the final choice becomes easy.

(ii) Let us start by equalizing the first attribute. The question asked is 'How much reduction in the number of work-days (per man per year) gained are you willing to accept in exchange for a further reduction in the infant mortality rate of 15 %?' The answer is, say, 2. The latter figure is then the rate of substitution between the first and fourth attribute. In other words one is equally well off with 40 of the first attribute and 13 of the fourth attribute as with 25 and 15 of the first and fourth attribute respectively. Table 2 summarizes this first stage of the procedure.
Table 2. Equalizing the reduction in infant mortality

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Health intervention</th>
<th>Health intervention 1a (= equivalent of intervention 1)</th>
<th>Health intervention 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in infant mortality, in %</td>
<td>25</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Reduction in child mortality, in %</td>
<td>12</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Reduction in adult mortality, in %</td>
<td>10</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Number of workdays gained per year per man</td>
<td>15</td>
<td>13</td>
<td>14</td>
</tr>
</tbody>
</table>

The next step is to equalize the second attribute. The question that is to be asked here is 'How much reduction in the number of work-days (per man per year) gained are you willing to accept in exchange for a further reduction in the child mortality rate of 2 %?'. Suppose the rate of substitution is 0.3. The result of this step is now portrayed in Table 3.
Table 3. Equalizing the reduction in child mortality

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Health intervention 5</th>
<th>Health intervention 5a (= equivalent of intervention 5)</th>
<th>Health intervention 1a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in infant mortality, in %</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Reduction in child mortality, in %</td>
<td>10</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Reduction in adult mortality, in %</td>
<td>12</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Number of workdays gained per year per man</td>
<td>14</td>
<td>13.7</td>
<td>13</td>
</tr>
</tbody>
</table>

In the last step, we equalize the third attribute. Here we have to ask the question 'How much reduction in the number of work-days (per man per year) gained are you willing to accept in exchange for a further reduction in the adult mortality rate of 2 %?'. Assume the rate of substitution is again 0.3. The result is given in Table 4.

One can see from Table 4 that the choice becomes simple because only one attribute needs to be compared. Project 5 will be selected as the best because its equivalent (5a) dominates the rival project's equivalent (1b).
Table 4. Equalizing the reduction in adult mortality

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Health intervention 1a</th>
<th>Health intervention 1b (=equivalent of intervention 1a)</th>
<th>Health intervention 5a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in infant mortality, in %</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Reduction in child mortality, in %</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Reduction in adult mortality, in %</td>
<td>10</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Number of workdays gained per year per man</td>
<td>13</td>
<td>12.7</td>
<td>13.7</td>
</tr>
</tbody>
</table>

(iii) As is clear by now, all that one needs for this procedure is the willingness on the part of the decision-maker to make explicit trade-offs between the various attributes; another prerequisite is of course that the attributes' values can be manipulated in negative and positive directions.

6. Econometric modeling

6.1. Definition

Econometric models (EM) of the health care sector formulate relationships between health and economic variables by means of a set of mathematical equations. Various statistical procedures can be used to estimate the parameters in those equations.
advantage of EM vis-à-vis the other techniques is that it is more comprehensive and that explicit attention can be given to direct as well as indirect interactions between variables. EM can also study in greater depth how the health sector and the economy at large are intertwined. One therefore says sometimes that the EM approach is a general equilibrium approach whereas the techniques previously studied are of the partial equilibrium type.

Let us next discuss the four types of equations in an EM. First, behavior equations imply a number of assumptions about the economic behavior of individuals, the government, health personnel etc. For instance, the demand equation for health care by individuals is a behavior equation, since it reveals how individuals' health care demand changes as a result of movements in variables such as price, income etc. Secondly, technical equations describe the relation between an output and a series of inputs. The notion of output has to be understood in a wide sense here: it not only refers to production of commodities or services but it also encompasses output in terms of life expectancy, lives saved due to health interventions, the birth rate, the weight and height of an individual etc. The inputs are to be seen as technical determinants of the output. For instance, the nutritional status may be considered as an input in the production of an individual's weight. Thirdly, institutional equations reflect relationships imposed by law or custom. Suppose that in a certain country, a complementarity is imposed between the numbers of nurses and doctors. In that case, regressing the variable nurses on the variable doctors would result in an institutional equation. Fourthly, identities specify relations that are true by definition. For instance, the variable 'population per doctor' is equal to the variable 'population' divided by the variable 'number of doctors'.

1See Barten (1980)
Variables are either endogenous or predetermined. The former are always determined within the model. The latter can be either lagged endogenous variables, viz. variables whose values are determined in previous time periods within the model, or exogenous variables that are determined outside the model. The exogenous variables that are controlled by the government can be called instrument variables. For instance, a typical instrument variable would be the government expenditures for the prevention of parasitic diseases. If government has set certain targets for the endogenous variables (e.g. life expectancy, infant mortality etc.), it will have to search for the values of the instrument variables that will help to satisfy these targets. Alternatively, government can investigate, by means of simulation analysis, the impact of different health intervention scenarios on the endogenous variables.

6.2. The health sector in an econometric model: an example

(i) Let us construct as an example a model of the role of primary health services in the economy of an imaginary developing country. Primary health services are meant here to contain, besides curative services by health personnel, efforts aiming at the improvement of sanitary conditions, health education and nutrition status, the knowledge of birth control methods and the eradication of vectors of parasites. Note that we will keep the structure of this model as simple as possible.

(ii) Before presenting the equations of the model, we would like to refer the reader first to Figure 6 where the linkages between the variables are depicted. The variables' symbols are explained in Table 5. The equations are now the following:

\[ PF = f^1(LF, LQF, CF) \]

\[(6.1)\]

\[ + + + \]

1The sign under an explanatory variable gives the direction of the likely impact upon the dependent variable. The symbol f refers to 'function'. In eq. (6.5), -1 refers to a one year lag.
\[ \text{PNF} = f^2(\text{LNF}, \text{LQN}, \text{CNF}) \quad (6.2) \]
\[ \text{NI} = \text{PF} + \text{PNF} \quad (6.3) \]
\[ \text{HI} = \text{NI} - \text{EI} - \text{GI} \quad (6.4) \]
\[ \text{POP} = \text{POP}_{-1}(1+\text{PGR}) \quad (6.5) \]
\[ \text{HIC} = \text{HI}/\text{POP} \quad (6.6) \]
\[ \text{DFC} = f^3(\text{HIC}, \text{FPR}) \quad (6.7) \]
\[ \text{FAC} = (\text{PF} + \text{MF})/\text{POP} \quad (6.8) \]
\[ \text{RFC} = \text{Min}(\text{FAC}, \text{DFC}) \quad (6.9a) \]
\[ \text{If MFRC} > \text{RFC, then MAL} = \text{MFRC} - \text{RFC} \quad (6.9b) \]
\[ \text{PGR} = f^4(\text{MORT}, \text{MORTIC}, \text{BIRTH}) \quad (6.10) \]
\[ \text{BIRTH} = f^5(\text{HIC}, \text{MORTIC}, \text{BC}) \quad (6.11) \]
\[ \text{CUR} = \alpha_1 \text{GI} \quad \alpha_1 > 0 \quad (6.12) \]
\[ \text{SAN} = \alpha_2 \text{GI} \quad \alpha_2 > 0 \quad (6.13) \]
\[ \text{EDUC} = \alpha_3 \text{GI} \quad \alpha_3 > 0 \quad (6.14) \]
\[ \text{NUTRI} = \alpha_4 \text{GI} \quad \alpha_4 > 0 \quad (6.15) \]
\[ \text{PARA} = \alpha_5 \text{GI} \quad \alpha_5 > 0 \quad (6.16) \]
\[ \text{BC} = \alpha_6 \text{GI} \quad \alpha_6 > 0 \quad (6.17) \]
\[ \text{MORT} = f^6(\text{CUR}, \text{SAN}, \text{EDUC}, \text{NUTRI}, \text{PARA}, \text{BC}, \text{MAL}) \quad (6.18) \]
\[ \text{MORTIC} = f^7(\text{CUR}, \text{SAN}, \text{EDUC}, \text{NUTRI}, \text{PARA}, \text{BC}, \text{MAL}) \quad (6.19) \]
\[ \text{MORBID} = f^8(\text{CUR}, \text{SAN}, \text{EDUC}, \text{NUTRI}, \text{PARA}, \text{BC}, \text{MAL}) \quad (6.20) \]
\[ \text{DEB} = f^9(\text{CUR}, \text{SAN}, \text{EDUC}, \text{NUTRI}, \text{PARA}, \text{BC}, \text{MAL}) \quad (6.21) \]
\[ \text{LF} = \beta_1 \text{L} \quad \beta_1 > 0 \quad (6.22) \]
\[ \text{LNF} = \beta_2 \text{L} \quad \beta_2 = 1 - \beta_1 \quad (6.23) \]
\[ \text{L} = \beta_3 \text{POP} \quad \beta_3 > 0 \quad (6.24) \]
\[ \text{LQF} = f^{10}(\text{DEB}) \quad (6.25) \]
\[ \text{LQN} = f^{11}(\text{DEB}) \quad (6.26) \]
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
<td>Birth Control</td>
</tr>
<tr>
<td>BIRTH</td>
<td>Birth rate</td>
</tr>
<tr>
<td>CF</td>
<td>Capital in food sector</td>
</tr>
<tr>
<td>CNF</td>
<td>Capital in non-food sector</td>
</tr>
<tr>
<td>CUR</td>
<td>Curative services</td>
</tr>
<tr>
<td>DEB</td>
<td>Debility</td>
</tr>
<tr>
<td>DFC</td>
<td>Demand for food per capita</td>
</tr>
<tr>
<td>EDUC</td>
<td>Health education</td>
</tr>
<tr>
<td>EI</td>
<td>Income of enterprises</td>
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<td>FAC</td>
<td>Food availability per capita</td>
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<tr>
<td>FPR</td>
<td>Food prices</td>
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<td>GI</td>
<td>Government income</td>
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<td>HI</td>
<td>Household income</td>
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<tr>
<td>L</td>
<td>Labor</td>
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<td>Labor in food sector</td>
</tr>
<tr>
<td>LNF</td>
<td>Labor in non-food sector</td>
</tr>
<tr>
<td>LQF</td>
<td>Quality of labor in food sector</td>
</tr>
<tr>
<td>LQNF</td>
<td>Quality of labor in non-food sector</td>
</tr>
<tr>
<td>MAL</td>
<td>Malnutrition</td>
</tr>
<tr>
<td>MF</td>
<td>Food imports</td>
</tr>
<tr>
<td>MFRC</td>
<td>Minimum Food requirements per capita</td>
</tr>
<tr>
<td>MORB</td>
<td>Morbidity</td>
</tr>
<tr>
<td>MORT</td>
<td>Mortality above age 4</td>
</tr>
<tr>
<td>MORTIC</td>
<td>Infant and child mortality age 0-4</td>
</tr>
<tr>
<td>NI</td>
<td>National income</td>
</tr>
<tr>
<td>NUTRI</td>
<td>Nutrition intervention</td>
</tr>
<tr>
<td>PARA</td>
<td>Parasitic disease control</td>
</tr>
<tr>
<td>PF</td>
<td>Production of food</td>
</tr>
<tr>
<td>PGR</td>
<td>Population growth</td>
</tr>
<tr>
<td>PNF</td>
<td>Production of non-food</td>
</tr>
<tr>
<td>POP</td>
<td>Population</td>
</tr>
<tr>
<td>RFC</td>
<td>Real food consumption per capita</td>
</tr>
<tr>
<td>SAN</td>
<td>Improvements in sanitary conditions</td>
</tr>
</tbody>
</table>
Figure 6:
Example of linkages between health and the economy
(iii) Most of the equations are of the technical type or are identities. As technical equations, we have first the production functions (6.1) and (6.2) where the inputs labor and capital determine production. Then we have equations (6.8) to (6.21) that describe the relationships between health outputs or health indicators and a number of health inputs. Finally we have equations (6.25) and (6.26) that explain quality of labor by debility. There are two behavioral equations: there is a demand for food equation (6.7) and the birth rate equation (6.11). The latter is qualified as a behavioral equation because it reflects human attitudes towards fertility that are determined by income, infant and child mortality and birth control measures. Income is supposed to have a negative effect upon birth rate because increasing welfare is likely to have a depressing effect upon the demand for children. Infant and child mortality has also positive effect on BIRTH. This can be explained by the fact that many parents in developing countries try to compensate for the eventual death of children by a high fertility rate. The negative effect of birth control measures on BIRTH is obvious. Equations (6.12) to (6.17), (6.22) to (6.24) and (6.27) to (6.28) are of the institutional type. The parameters (in greek letters) in those equations can be dictated by governmental decisions. We see that the allocation of health inputs, and of labor can be influenced by government. The other equations in the model are identities. Identity (6.9) measures the degree of malnutrition per capita and is equal to the minimum food requirements minus the real food consumption (RFC). Equations (6.9) only function in the model if MFRC exceeds RFC. Notice that RFC is the minimum of food availability and demand for food per capita. The latter has to be added to a model for a developing country because, although DFC may exceed MFRC, there is no certainty that this demand can be met. Indeed in most countries, this demand is constrained by the food availability, necessitating the Min condition in the model.

The exogenous variables in the model are income of enterprises (EI), income of government (GI), food prices (FPR), minimum food requirements (MFRC), imports of food (MF) and capital (CF and CNF). The parameters in the institutional equation can also be
considered as 'variables' to be manipulated by government.

6.3. The health sector in an econometric model: further comments

(i) First, although the model above is basically simple, we see that it can already take account of a number of important linkages between health and economic variables. These linkages are also sometimes very unexpected.

Secondly, the health indicator equations show a variety of determinants. The econometric estimations will have to reveal the precise impacts of each determinant on the health indicators. Knowing the latter is very important if government wants to figure out which combination of health inputs optimizes the health outputs.

Thirdly, malnutrition is included as a determinant in the health output equations. This implies that the positive impact of primary health care policies can be mitigated or annihilated by inadequate food policies. For instance, the following scenario is possible. Due to increased health interventions, mortality rates are likely to decrease. The latter increases population growth and the overall demand for food. If production of food is inadequate and if imports of food are limited (due to balance of payments problems, say), malnutrition may arise and may wipe out the temporary gains of health interventions. Government can then search for policies that undo the malnutrition: food prices can be manipulated, more labor and capital can be allocated to agricultural production or more food can be imported.

The main advantage of this model approach is that it quantifies the direct and indirect linkages among variables. If a model is of the general equilibrium type, the EM approach is likely to prevent decision-makers from neglecting the linkages between health and the economy.
(ii) It is granted that the model described above is rather crude. Yet, nothing prevents the health researcher from going into detail and from incorporating complex epidemiological phenomena into a model. It may even be that one does not want to analyze health problems in a macro context but that one prefers micro analysis. In the latter case, the same econometric methodology as sketched above can be applied, however.
7. Conclusion

The techniques discussed above can be used at various instances: when deciding about a single health intervention project or about a combination of projects. Also when elaborating a health plan can techniques be used. Indeed at a certain stage of a health plan, alternative courses of health interventions are to be discussed. A comparison between alternatives can now certainly be facilitated by the use of economic evaluation techniques.

This review should also make clear that there is no unique evaluation method. The choice of the method will frequently be influenced by the health researcher's own preferences. If he is willing to measure health benefits and costs in monetary terms, he is likely to use CBA or CEA. If he is interested in the multidimensional character of health, he will be attracted by MPA. If he wants to optimize a health objective given a number of structural constraints, he may prefer to use LP. If he is concerned about the direct and indirect spillovers health interventions on the economy, he may want to use EM. In a number of cases, the choice of technique is dictated by the availability of information, however.

Studies that use economic evaluation techniques are not numerous. Yet, some that make use of them are very interesting and worthwhile to be examined. We present a list of such studies in the Appendix. This list is not exhaustive, however. Its only purpose is to show that economic evaluation techniques can be used successfully. It is hoped that the present review will also contribute to a wider use of techniques. Remark however that the use of techniques per se is not aimed at. It is mainly the results of the evaluation exercises that should be used in order to come nearer to predetermined health objectives.
<table>
<thead>
<tr>
<th>Authors</th>
<th>Subject of study</th>
<th>Type of method</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barlow [1967]</td>
<td>Economic effects of Malaria Eradication in Ceylon</td>
<td>EM</td>
<td>The study analyses the effects of malaria eradication within the context of a macro-economic model for the Ceylonese economy.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(i) Benefits include the value of income derived from prevented mortality, the avoided treatment costs and the value of non services time saved in the care of the sick.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(ii) Costs are put equal to the program's money cost. Productivity levels of anemic and non-anemic workers are compared. The benefit/cost ratio of the intervention is as high as 260:1.</td>
</tr>
<tr>
<td>Barnum [1981]</td>
<td>Economic costs and benefits of an immunization program (DPT, IFT, BCG) in Indonesia</td>
<td>CBA</td>
<td></td>
</tr>
<tr>
<td>Bastia and Churchill [1974]</td>
<td>The impact of iron deficiency anemia on the productivity of adult males in Indonesia</td>
<td>CBA</td>
<td>(i) Benefits are put equal to the increase in output due to extension of working lives. Total benefits are underestimated because no account taken of increased output due to decreased absenteeism and increased efficiency.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(ii) It is not a complete CBA study since costs are not studied.</td>
</tr>
<tr>
<td>Cohen [1974]</td>
<td>Economic benefits of eliminating mortality attributed to schistosomiasis in Zanzibar</td>
<td>CBA</td>
<td></td>
</tr>
<tr>
<td>Grosse [1979]</td>
<td>Application of a health development model to rural Java</td>
<td>EM CEA MPA</td>
<td>The model contains the relationship between health status indicators and health care strategies (EM). Costs and health effects of different options are then computed. CEA and MPA are used in the case of single and multiple objectives respectively.</td>
</tr>
<tr>
<td>Heller [1975]</td>
<td>Costing of public medical services of Malaysia</td>
<td>CEA</td>
<td>The study describes the methodology for estimating unit costs of Malaysia's public medical care services. As such it provides the data for performing CEA.</td>
</tr>
<tr>
<td>Hicks [1980]</td>
<td>Economic growth and human resources</td>
<td>EM</td>
<td>Studies the relationships between economic growth, life expectancy and literacy by means of cross-section regression analysis, using country data.</td>
</tr>
<tr>
<td>Morrow, Smith and Nimo [1980]</td>
<td>Assessing the health impact of different diseases in less developed countries</td>
<td>CEA</td>
<td>Uses as objective the minimization of 'healthy days of life lost'.</td>
</tr>
</tbody>
</table>
Rietschin [1981]  
Interrelation between health inputs and health outputs  
EM  
These studies contribute to the understanding of the relationships between health output (such as mortality, life expectancy etc.) and health inputs (such as economic, demographic and social indicators, health personnel and facilities). Cross section regression analysis, using country data, is performed.

Grosse [1980]  
Cochrane [1978]  
Rosenfield [1977]  
A model of the transmission of Schistosomiasis  
EM  
CEA  
The study specifies econometric relationships for the transmission of schistosomiasis. In addition CEA of different control methods is performed.

Stephenson, Latham and Oduori [1980]  
Benefits and costs of control of Ascaris infection in Kenya  
CBA  
(i) Benefits are equal to the current costs of ascariasis control (the cost to the health care system, the cost of anthelmintics and the costs of private citizens) that would be saved under an alternative program. 
(ii) Costs are equal to the drug treatment costs of the alternative program.

Weisbod and Helminiak [1977]  
Parasitic diseases and agricultural labor productivity in St. Lucia  
EM  
The impact is measured of various parasitic diseases (schistosomiasis, ascariasis, trichuriasis, hookworm, strongyloidiasis) on the labor supply and labor productivity of 458 St. Lucia workers.

Wheeler [1980]  
A simultaneous model of human resource development and economic growth in developing countries  
EM  
The study contains a cross section regression analysis, using country data, of the linkages between economic growth, improvements in education health and nutrition, and population growth in developing countries.
Bibliography


Culyer A.J., Lavers R.J. and Williams A. [1971], 'Social Indicators: Health', Social Trends, n° 2, pp. 31-42.


