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Cost-Effective Integration of Immunization and Basic Health Services in Developing Countries: The Problem of Joint Costs

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The debate between those who favor delivering comprehensive primary health care from fixed health centers and those who favor delivering selective primary care from mobile health teams can be decided, in principle, on empirical grounds. Key requirements for choosing the more cost-effective approach in a given developing country are (1) an effectiveness measure common to both types of health care programs and (2) an approach to modeling joint costs.

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With limited budgets for rural primary health care, developing countries are under pressure to integrate the basic medical services that government health centers provide with the vaccination programs that mobile immunization teams handle. For health planners, the question is whether to organize the integrated services around the fixed health centers or around the mobile health teams. Implicit in this decision is a choice between more comprehensive health care from the fixed center versus more selective care from the mobile teams.

Application of cost-effectiveness analysis is complicated by two inherent difficulties. First, because the two types of health care programs improve the health of different target groups, some common measure of the effectiveness of the two programs must be agreed upon. Here the healthy-life-years saved by the two alternative programs is proposed and implemented as a useful common measure of effectiveness.

The second difficulty is that of modeling the joint costs of simultaneously producing more than one health care service. In some situations the degree of "jointness" of the cost structure and the associated production technology have an important impact on the relative cost-effectiveness of the two alternative approaches.

Using the method described here, economists can address this problem in a way that does justice to both the superior efficiency of the mobile teams and the superior comprehensiveness of the fixed centers. Special purpose models such as this one can guide policy decisions since they are less complex than more general models and can be easily understood by decisionmakers.

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by
Mead Over

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I. Introduction

The delivery of life-saving primary health care (PHC) to the rural poor of less developed countries (LDCs) has been a goal of almost all of these countries' governments since the Alma Ata Conference of 1978, if not before (World Health Organization, 1978). To achieve this goal, each LDC must choose how much of its limited recurrent budget to allocate to rural primary health care, what mix of health care services to deliver with this limited budget and how to organize and manage their delivery. As the scarcity of LDC recurrent budgetary resources grows more acute, ministries of health (MOHs) are being urged to focus on consolidating and enhancing the efficiency of current programs rather than on implementing new ones. However, the search for efficiency "will raise difficult questions about trade-offs [such as] the choice between disease-specific, vertically organized health services and the multi-purpose, horizontal [basic health services] approach" (Evans, Hall and Warford, 1981, p. 1124).

The choice between vertical immunization programs using mobile vaccination teams and horizontal basic health services programs using polyvalent village health workers (VHWs) is particularly painful because the two types of programs attack different high priority diseases. An alternative to this choice is to integrate both VHWs and vaccination into a program that is more cost-effective than either would be alone. Indeed this kind of integration has been achieved in some of the most successful primary health care experiments (Gwatkin, Wilcox and Wray, 1980; Berggren, Ewbank and Berggren, 1981). For the integrated program to be cost-effective, the two critically scarce and expensive inputs, transport and management skill, must be conserved by the chosen integration strategy. There are at least two different integration strategies which fulfill this criterion and again a choice must be made.

On the one hand, immunization activities can be added to the functions of the horizontally organized government health centers which also function as the support system and referral target for the VHWs who deliver basic health services. The MOH that follows this strategy chooses to allocate its limited transportation budget to the support and supervision of fixed centers and to trips by fixed center personnel to supervise VHWs, rather than to vertically organized mobile vaccination teams. Villagers could obtain vaccinations on pre-specified days at the center, but most vaccination would be done by the fixed-center-based VHW supervisor when he or she visits the VHWs in their villages several times a year. In the rest of this paper this integration strategy is referred to as "Strategy F."

On the other hand, VHW support and supervision could be added to the tasks of the vertically organized mobile vaccination team. With this option, "Strategy M," the fixed centers would have no responsibility for either vaccination or VHW supervision, but might remain involved with basic health services as the training sites and referral targets for the VHWs.[1]

The planner who attempts to choose between these two integration strategies for a given country or region of a country will not lack for advocates of the two alternatives. Primary health care experts are likely to prefer Strategy F, the approach that allocates the transport to the support of the VHWs, while immunization experts will probably prefer Strategy M, because it allocates transport to the mobile vaccination teams. However, when the planner turns to the economist for guidance in choosing a cost-effective integrated program, he may be told that "there is no general solution" to the problem of allocating joint costs among several outputs of a program and that the results of applying cost-effectiveness analysis to such a program, "although ... not capricious, ... are arbitrary and subject to change when other, perhaps equally plausible, [allocation] rules are adopted" (Klarman, 1982, p. 595).

The goals of this paper are to contribute to the methodology of cost-effectiveness analysis in the presence of joint outputs and to address the substantive problem of primary health care integration in developing countries. The paper characterizes the planner's choice problem in a way that avoids the need to allocate joint costs, while capturing both the superior efficiency of mobile teams at producing vaccinations alone and the greater degree of complementarity between VHW support and vaccinations in fixed centers. The model is set out in general terms in Section II and then with sufficient structure that a decision rule can be derived in Section III. Section IV derives preliminary estimates of the parameters of the decision rule from available information on the epidemiology and costs of rural primary health care in developing countries and uses these estimates to illustrate the application and interpretation of the proposed decision rule. Section V contrasts the model developed in this paper to two other large programming models, remarks on the impact of uncertainty on the proposed decision rule and suggests directions for fruitful res

II. The Planner's Decision Problem

A convenient index of a health strategy's success in reducing both morbidity and mortality is the number of "healthy-life-days" that the strategy saves (Ghana Health Assessment Team, 1981). By counting a day of reduced health as only a fraction of a day of full health, this index is able to summarize in one number the effects of a policy on both mortality and morbidity. As applied here, the healthy-life-days index weights a child's life-day the same as that of a working adult, but it would be straightforward for a country which applies this decision process to develop its own weights for life-days saved in each rural demographic group. [2]

In the context of the present decision problem, there are two health sector activities that could potentially contribute to the healthy-life-days of rural citizens: VHW services and immunization services. Each of these aggregates is itself a mix of different elementary activities.

VHW services can, in turn, be further disaggregated among preventive consultations, curative drug dispensing and referrals to the local clinic or dispensary. Typically the VHW, the villager-patients and the health ministry will have different opinions regarding the "best" mix of these three categories of services. The mix actually achieved in the field will depend upon a variety of factors including the quantity and quality of VHW supervision, the pecuniary and non-pecuniary rewards attached to each kind of service, the distance of the VHW from other care providers, the price and quality of those alternatives, and so on. Let the term "encounter" refer to any health-related contact between a villager and a VHW. Then the three different categories of encounters can be represented by e_1, e_2 and e_3. [3]

Immunization services can also be disaggregated among vaccinations for different diseases and then among the first and subsequent vaccinations for diseases that require more than one. The "expanded program of immunization" (EPI) recommended by the World Health Organization is designed to protect against six diseases through the administration of four vaccines, two of which are to be administered three times each. Thus there are eight distinct vaccination services delivered by an EPI. Taking such a program as the norm, let $v_1, v_2, \ldots, v_8$ represent the eight distinct vaccination services that are relevant to a given LDC.

With healthy-life-days represented by h, the health planner's objective function is given by:

$$H = h(\underline{e}, \underline{v}, \underline{x}) ,$$

where $\underline{e}$ and $\underline{v}$ represent respectively the vectors of subscripted encounter variables and vaccination variables. The function H is assumed convex and increasing in all of the elements of $\underline{e}$, $\underline{v}$ and $\underline{x}$. The variables in $\underline{x}$ represent other health sector activities and the environmental, behavioral and socio-economic determinants of health, which are all assumed to be independent of the chosen primary health care integration strategy. In the rest of this paper these variables are held constant at $\underline{\bar{x}}$.

In attempting to maximize h subject to a given annual operating budget, the health planner faces one of two different recurrent cost constraints depending on whether the fixed or mobile strategy is followed.[4] Let $\underline{p}$ be a vector of the prices of inputs such as the wages of the various manpower categories, the prices of gasoline for transport, kerosene for refrigerators, essential drugs and vaccines, or office supplies. Then denote the "fixed" and "mobile" primary health care integration strategies by the subscripts f and m, respectively. The recurrent cost functions for the two strategies can be written:

$$C_f = c_f(\underline{e}, \underline{v}, \underline{p}) ,$$

$$C_m = c_m(\underline{e}, \underline{v}, \underline{p}) ,$$

where the c_f and c_m functions are increasing in (the elements of) $\underline{e}$, $\underline{v}$ and $\underline{p}$, concave in $\underline{e}$ and $\underline{v}$, and homogeneous of degree one in $\underline{p}$.[5]

If these functions are known, then the planner must solve two constrained optimization problems and then compare the two optimal solutions. If the maximum annual recurrent budget for the health planning region is represented by C^* and the vector of expected input prices by $\underline{\hat{p}}$, then the two problems are:

<u>For Strategy F:</u>

$$\max h(\underline{e}, \underline{v}, \underline{\bar{x}})$$

subject to:

$$c_f(\underline{e}, \underline{v}, \underline{\hat{p}}) \leq C^* ,$$

<u>For Strategy M:</u>

$$\max h(\underline{e}, \underline{v}, \underline{\bar{x}})$$

subject to:

$$c_m(\underline{e}, \underline{v}, \underline{\hat{p}}) \leq C^* .$$

By solving each of the two problems for the optimal vectors of encounters and vaccinations and then substituting those optimal vectors into $h(\underline{e}, \underline{v}, \underline{x})$ it is possible to compute the number of healthy life days that would be saved by each strategy. Call these amounts H_f and H_m. Then the health planner's decision rule is just to choose the strategy that saves the larger number of healthy life days for the given budget. In other words:

Decision Rule:

If $H_m > H_f$, choose Strategy M. (Case 1)
If $H_m < H_f$, choose Strategy F. (Case 2)
If $H_m = H_f$, choose either strategy. (Case 3)

Thus the problem of choosing the most cost-effective integration strategy for rural primary health care is easily solved once the functions h, c_f and c_m are known. Since the activities $\underline{e}$ and $\underline{v}$ are all judged in terms of life-days-saved, it is neither necessary nor desirable to allocate joint costs among these activities. Therefore the arbitrariness of such allocations highlighted by Klarman (1982, p. 595) and others does not attach to the analysis.[6] The fact that present-day knowledge is inadequate to specify these functions with much confidence creates the prevailing uncertainty about which is the correct integration strategy. On the basis of some assumptions regarding the nature of these functions, the next section illustrates how a precise decision rule can be developed for a given region and discusses the behavior of that rule under various circumstances.

III. A Rule for Choosing the Cost-Effective Integration Strategy

To simplify the characterization of the objective function h and the cost functions c_f and c_m, assume that the cost-effective mix of VHW services e_1, e_2 and e_3 is constant and therefore independent of such variables as the scale of the program, the ratio of vaccination services to VHW services and whether Strategy F or Strategy M is chosen. In this case the three VHW services should be produced in fixed proportions and can be represented by the simple sum of the three types of encounters. Let e represent this scalar sum of the elements of $\underline{e}$. Adopting a similar assumption for the eight different vaccination services allows vaccination activity to be represented by the simple sum of all vaccinations performed, v. Then a first-order approximation to the objective function, $h(e, v, \underline{x})$, can be written:

$$H = h_0 + a e + b v , \qquad (1)$$

where a represents the number of healthy-life-days saved by an average VHW encounter and b represents the number of healthy-life-days saved by an average vaccination. The intercept h_0 is the number of healthy-life-days lived in the absence of any VHW or vaccination activity and thus represents the baseline health status of the population.[7]

To do justice to the two competing integration strategies, their cost functions must capture their respective strengths. A functional form capable of representing the strengths of both strategies is:

$$c(e, v, \underline{p}) = A(\underline{p}) \, [(e/\mu)^{\beta} + v^{\beta}]^{(s/\beta)} , \qquad (2)$$

where $A(\underline{p})$ is a linear homogeneous increasing function of input prices, the parameters μ and s are strictly positive and β is greater than or equal to one. The parameters μ and s determine respectively the intercept of the isocost curve on the e axis and the degree of returns to scale of the production technology. The parameter β measures the degree of complementarity in the production of the two outputs of an integrated rural primary health care program. It is related to σ, the elasticity of product transformation, by $\sigma = 1/(\beta - 1)$.

Figure 1 depicts the shape of the isocost or production possibility frontier associated with equation (2) for four different values of β. When β equals one, there is no complementarity between e and v and the isocost curve is linear as in Figure 1a. For larger values of β the isocost curve bows outward, demonstrating increasing complementarity in the production of encounters and vaccinations. As β approaches infinity, the two outputs become joint products which should be produced in fixed proportions if both improve health status.[8] The next paragraphs bring to bear a few "stylized facts" in order to specify the relative magnitudes of the parameters of equation (2) for each of the two competing strategies.

Evidence from the Ivory Coast supports the observation that vertically organized mobile vaccination teams can be as much as twice as cost-effective as fixed centers at the delivery of vaccination services alone (Shepard, Sanoh and Coffi, 1982b). The observed difference in cost-effectiveness is probably due to the greater accountability and compliance that are properties of vertically organized management structures, the tight task definitions of the vaccination teams, their mobility and flexibility which allow them to go where the people are on a given day, the speed of their itinerary and the physical limit on the number of employees per vehicle which acts as an effective check on the political pressure to increase employment on the teams.

To capture this stylized fact, set e equal to zero in equation (2) and solve for v:

$$v = [\, C/A(\underline{p})\,]^{1/s} \,. \qquad (3)$$

The assumption that Strategy M is twice as cost-effective as Strategy F at the production of vaccinations alone can then be represented by supposing that, for the same recurrent budget C^*, the attainable value of v from equation (3) is twice as large for Strategy M values of $A(\underline{p})$ and s as it is for Strategy F values.[9] Call the number of vaccinations produceable from budget C^* by Strategy F, V^*. Then the number of vaccinations produceable from the same budget by Strategy M will be $2V^*$.

Advocates of fixed centers argue that once such a center is operating at a given annual recurrent budget and one of its staff is making periodic vaccination visits to the surrounding villages, the number of vaccinations that would have to be foregone for the traveling staff member to also supervise and support a VHW in each village would be quite small. In other words, the fixed center could add VHW supervision to its tasks at little "opportunity cost" in terms of foregone vaccinations. The technology of producing both VHW services and vaccinations from a fixed center can thus be characterized by substantial complementarity.

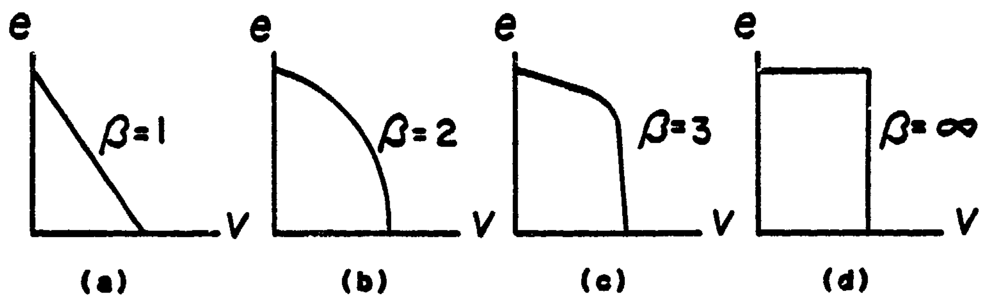


Figure 1. The Effect ‾ Varying β on the Production Possibility Frontier

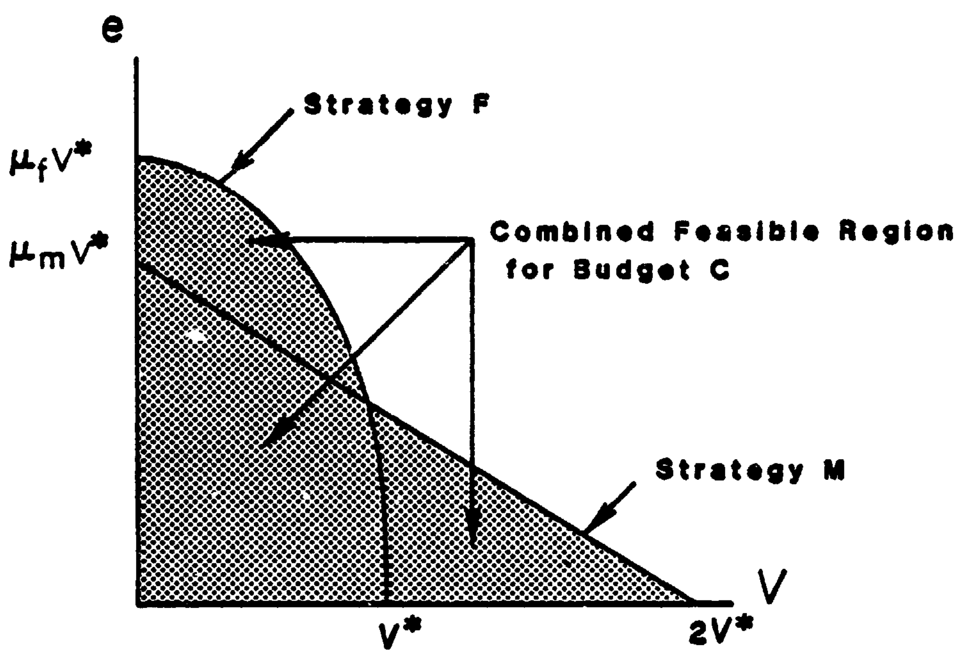


Figure 2. Superposition of the Feasible Combinations of e and v for Budget C* and the Two Strategies

Although there is no accumulated experience on the use of mobile vaccination teams to supervise VHWs, there is reason to be less sanguine about the effects of adding VHW supervision to their tasks. The very features of the mobile teams which make them so efficient for their given tasks, the tight task definitions, their mobility, the speed of their schedules and the physical limit on the number of employees per vehicle, imply that the addition of VHW supervision and support to team duties will substantially slow the progress of the team. In other words, for a given recurrent budget the opportunity cost of adding VHW support and supervision to the duties of the mobile team is likely to be high in terms of foregone vaccinations.

To capture this hypothesized difference in complementarity, suppose that the production technology for Strategy F demonstrates a modest degree of complementarity between encounters and vaccinations such as that shown in Figures 1b and 1c, while that for Strategy M demonstrates zero complementarity as illustrated in Figure 1a. Then β is two or greater for the Strategy F cost function while it equals one for the Strategy M function.

Finally consider the relative magnitudes of the parameter μ for the two strategies. For Strategy F and budget C^*, the parameter μ_f is defined as the ratio of the number of encounters produceable with no vaccinations to the number of vaccinations produceable with no encounters. Thus if V^* is the intercept of the Strategy F isocost curve with the v axis, then $\mu_f V^*$ is its intercept with the e axis.

While Strategy M is twice as cost-effective as Strategy F at producing vaccinations alone, it is unlikely to be more cost-effective than Strategy F at producing encounters alone.[10] To capture this last stylized fact, define μ_m for the given budget C^*, as the ratio of the number of encounters produceable by Strategy M with no vaccinations to the number of vaccinations produceable by Strategy F with no encounters (i.e. to V^*). Then μ_m will be less than μ_f, but greater than one. The intercept of the Strategy M isocost curve with the e axis is thus $\mu_m V^*$ as shown in Figure 2.

These assumptions allow the superposition of the production possibility frontiers for the two strategies operating under the same cost constraint. The equations for the two constraints are:

Strategy F:
$$[\,(e/\mu_f)^{\beta} + v^{\beta}\,]^{1/\beta} = V^* \tag{4}$$

Strategy M:
$$2\,(e/\mu_m) + v = 2\,V^* \tag{5}$$

where V^* is an increasing function of C^*.[11] Figure 2 depicts the combined feasible region for the two strategies. For budget C^* it is possible to attain any combination of e and v that is on the northeast boundary of the union of these two possiblity sets. The problem is to choose the best of these combinations and thereby to choose the best strategy.

Following the solution technique described in Section II, the first step is to maximize equation (1) with respect to e and v subject to equation (4), the Strategy F cost constraint and then to substitute the resulting values of e and v into equation (1) to obtain the maximum number of healthy-life-days that can be saved under budget C^* with Strategy F. The result is:

$$H_f = [a^{[\beta/(\beta-1)]} + (b/\mu_f)^{[\beta/(\beta-1)]}]^{(\beta-1)/\beta}\mu_f V^* \qquad (6)$$

where $\beta/(\beta-1) = (\sigma+1)$ and $\beta > 1$.

Because the possibility frontier for the mobile strategy is linear, the Strategy M maximization problem reduces to a choice between one of the two intercepts of that frontier with the e and v axes. That is, except in the special case where $b/a = \mu_m/2$, the mobile team should devote itself entirely to either vaccinations or encounters and should not mix the two tasks. Formally the maximization problem is:

$$H_m = \max \{ a\mu_m V^* ,\ 2\, b\, V^* \} . \qquad (7)$$

Since mobile teams could probably save many more healthy-life-days doing only vaccinations than doing only VHW supervision and support, the maximum value of H_m is:

$$H_m = 2\, b\, V^* . \qquad (8)$$

According to the decision rule of Section II, Strategy M is preferable if the number of life-days saved according to equation (8) exceeds the number saved according to equation (6). Forming this inequality and manipulating it yields the condition:

<u>Choose Strategy M if:</u>

$$\frac{b}{a} \quad > \quad \frac{\mu_f}{(2^{[\beta/(\beta-1)]} - 1)^{(\beta-1)/\beta}} \qquad (9)$$

where $\mu_f > 1$ and $\beta > 1$.

The left-hand-side of decision rule (9) reflects the marginal benefit of a vaccination relative to that of encounter while the right-hand-side contains parameters of the cost functions of the two strategies. According to the decision rule, if the number of healthy-life-days saved per vaccination is sufficiently larger than the number saved per encounter, then Strategy M's superior efficiency at vaccination guarantees that it will dominate Strategy F for saving life-days.

This decision rule has a simple graphic interpretation which can be exposited as three cases.

CASE 1: STRATEGY M DOMINATES. The ratio b/a can be represented graphically as the (absolute value of the) slope of the straight-line isoquant obtained from equation (1) by solving for e in terms of v and a fixed level of H. Thus condition (9) is equivalent to the requirement that the healthy-life-days isoquant be steep enough so that the highest attainable value of H is at the point $2V^*$ on the vaccination axis. This situation is depicted in Figure 3a where the optimal point is marked H^*. At this solution, Strategy M is used to perform only vaccinations.

Figure 3a.
Strategy M
dominates

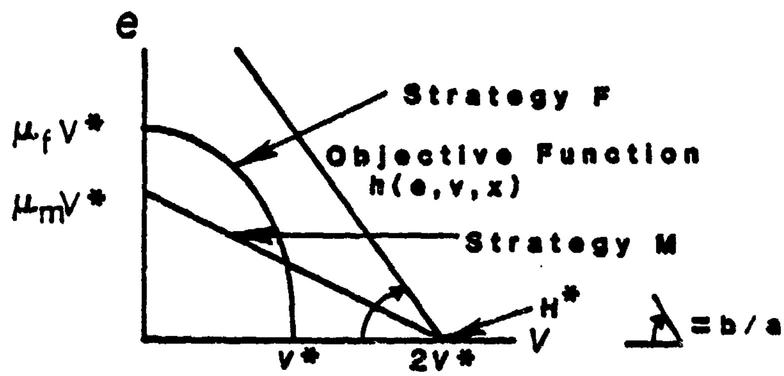


Figure 3b.
Strategy F
dominates

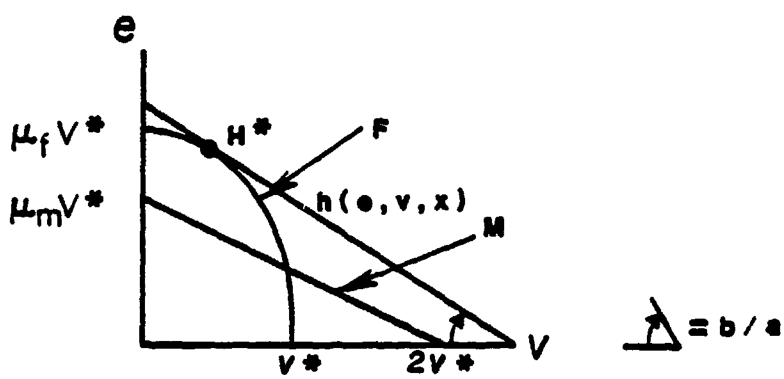
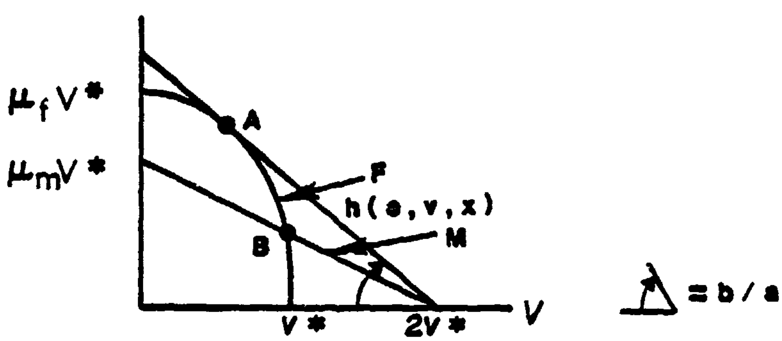


Figure 3c.
Neither
strategy
dominates



CASE 2: STRATEGY F DOMINATES. Although b is likely to be greater than a, it is possible that the ratio b/a is smaller than the right-hand-side of inequality (9). In this case the H isoquants are flatter than in Case 1. Therefore, the largest number of life-days-saved will be at the point of tangency between the highest attainable H isoquant and the Strategy F possibility frontier as illustrated by the point labeled H^* in Figure 3b. Because of the assumed complementarity of the Strategy F production process, this solution would imply that the fixed centers provide both encounters and vaccinations in the ratio determined by the slope of a ray from the origin to point H^*.

CASE 3: THE DECISION IS INDETERMINATE. If the slope of the H isoquant, b/a, is exactly the same as the slope of a straight line constructed to be tangent to the Strategy F frontier and to pass through the point $2V^*$ on the horizontal axis, the left- and right-hand-sides of (9) are equal. This boundary case (depicted in Figure 3c) is unlikely to obtain in practice, but is instructive for the light it throws on the role of the complementarity assumptions in the analysis.

First note in Figure 3c that the assumptions of some complementarity in Strategy F, but none in Strategy M, combined with the assumption that $h(e, v, \underset{\sim}{x})$ is linear, imply that the portions of the two possibility frontiers on segments ABC are always dominated either by point C on the Strategy M frontier or by a point at, or to the northwest of, A on the Strategy F frontier. Thus it is suboptimal to use Strategy M to support VHWs or to use Strategy F to focus predominantly on vaccination - whatever the health impacts of the two interventions.

As is intuitively clear, complementarity helps Strategy F to compensate for its relative inefficiency at vaccination. Figure 4a depicts the situation that would obtain if such complementarity were eliminated as ß approaches 1 (σ approaches infinity). In this case inequality (9) reduces to the requirement that b/a be greater than $\mu_f/2$, a less demanding requirement than (9). Thus in the absence of complementarity in the Strategy F production process, the strategy choice reduces to the simple choice between supporting encounters alone using fixed centers (at point A in Figure 4a) and delivering vaccinations alone using mobile teams (at point C in Figure 4a) - a choice which is more likely to favor mobile teams.

On the other hand, if Strategy F benefits from perfect complementarity in its production process as shown in Figure 4b, ß approaches infinity and condition (9) becomes the requirement that b/a exceed μ_f, a condition which is twice as hard to satisfy as the condition that b/a exceed $\mu_f/2$. Thus the assumption of complementarity in the Strategy F production process increases by as much as a factor of 2 the extent to which the health impact of vaccinations must exceed that of VHW services in order to render the mobile strategy more cost-effective at saving life-days.[12]

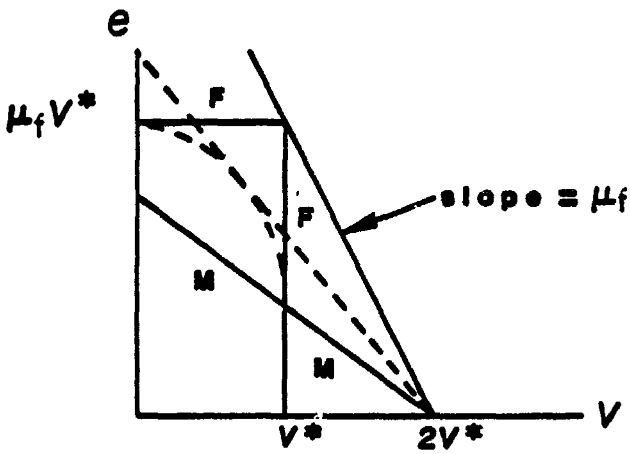


Figure 4a. Strategy F suffers from zero complementarity

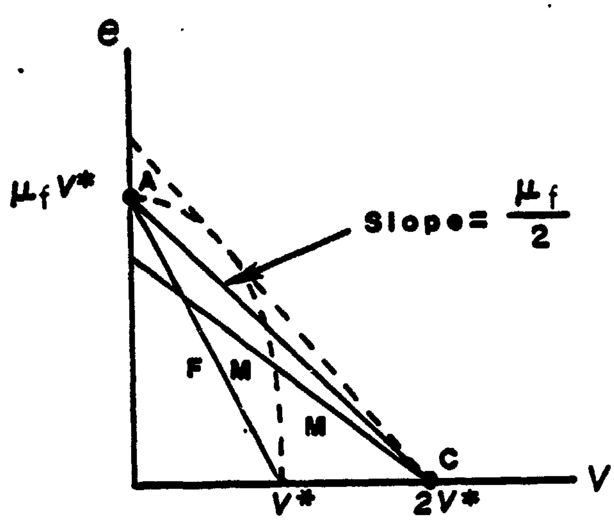


Figure 4b. Strategy F favored by perfect complementarity

IV. Applications and Interpretations of the Decision Rule.

If the values of the four parameters in decision rule (9) were known with confidence for a specific country or region of a country and the other assumptions of the analysis accepted, application of rule (9) would provide the cost-effective integration strategy. Unfortunately none of these parameters is known with precision for any country. This section applies information from three studies, on Ghana, Java, and the Ivory Coast, in order to arrive at tentative estimates of the parameters a, b and μ_f, life-days-saved per encounter and per vaccination and the intercept of the fixed-center isocost curve with the e axis. All of these estimates are drawn together to illustrate the application and interpretation of the decision rule in Table 7 at the end of the section.

1. Estimates of Healthy Life-Days-Saved Per Vaccination. Table 1 presents two estimates of b, the number of life-days-saved (LDS) per vaccination in an immunization program based on Ghanaian data and assumptions as presented by the Ghana Health Assessment Team (1981).[13] The first estimate of 75.4 LDS per vaccination at the bottom of column (7) is based on the theoretical distribution of the various vaccinations in that column. The second estimate of 53.8 LDS per vaccinatioon at the bottom of column (8) is based on an empirical distribution of vaccinations observed in neighboring Ivory Coast. Apparently it is difficult to maintain the proper ratio of measles vaccines to other vaccines and to deliver the third doses of the polio and DPT vaccines. Since the third doses add less than the average to LDS, reducing their proportions increases the average of the program. However, since measles vaccination has at least thirty times more impact on LDS per vaccination than any of the others, reducing its proportion even slightly has a large negative effect on the average LDS per vaccine.

Table 2 presents in columns (8) and (9) the raw material for developing a comparable estimate of b based on Javanese data and assumptions as developed and analyzed by a University of Michigan study (Grosse et al, 1979).[14] In a rural population of 50,000, the Michigan study estimated that an immunization program consisting of 27,000 administered doses per year would reduce mortality and morbidity to a degree which is calculated here to save 1,790 life years through averted deaths and 22,500 days of partial or total disability. Thus on average the Javanese vaccination program is estimated to save 25.0 healthy-life-days per vaccination, a figure which is of the same order of magnitude as the estimates for Ghana from Table 1.

However the Javanese immunization program considered by the Michigan study differs in three ways from the immunization program presented in Table 1. The Javanese program includes a vaccination of 2100 mothers per year for neonatal tetanus but excludes vaccinations against measles and polio. By referring to the Michigan report, it is possible to estimate the value of b that would obtain in Java if the vaccination program resembled that in Table 1.

Table 1. Estimation of the Average Number of Life-Days Saved Per Vaccination from Ghanaian Data

Vaccination/ Dose (1)	Life-Days-Lost (2)	Prop. at Risk (3)	Poten-tial LDS (4)	Prop. Prdcng Im'ty (5)	LDS Per Vac. (6)	Distributions of Vaccinations: Theory (7)	Obsrvd. (8)
1. Measles	23.36	.039	599.0	.60	359.38	.191	.128
2. Tuberculosis	11.01	1.00	11.01	.90	10.45	.142	.152
3. Polio/1	1.20	.038	15.8	.90	.57	.111	.180
4. Polio/2			7.9	.90	.29	.111	.096
5. Polio/3			7.9	.90	.29	.111	.084
6. Diptheria/1	.014	.077	.086	.90	7.08	.037	.060
7. Diptheria/2			.078	.90	6.65	.037	.032
8. Diptheria/3			.018	.90	1.57	.037	.028
9. Pertussis/1	4.65	.078	23.8	.90	21.46	.037	.060
10.Pertussis/2			23.8	.90	21.46	.037	.032
11.Pertussis/3			11.9	.90	10.73	.037	.028
12.Tetanus/1	4.47	.961	2.2	.90	1.99	.037	.060
13.Tetanus/2			2.2	.90	.22	.037	.032
14.Tetanus/3			.2	.90	.22	.037	.028
TOTALS	44.70		706.0			75.4	53.8

SOURCES: Table 1 of Ghana Health Assessment Team (GHAT) (1981) and the appendix to it distributed by R. Morrow, WHO, Geneva.

Column (2): Expected life-days-lost per capita in entire population from GHAT, Table 1, column (10).

Column (3): Proportion of entire population which is at risk from this disease and thus can benefit from the vaccination. Measles - pop. 1-2 assumed 39/1000 (GHAT Appendix); TB - entire population; polio - pop. 2-3 assumed 38/1000 (GHAT Appendix); Dip. - pop. 1-3 assumed 77/1000; pert. - pop. 0-2 assumed 78/1000; Non-neonatal tet. - pop. older than 1 yr. assumed 961/1000.

Column (4): Column (2) / column (3). Quotient is allocated among multiple doses as follows: polio: 50%, 25%, 25%; dip.: 47.5%, 47.5%, 5%; pert.: 40%, 40%, 20%; tet.: 47.5%, 47.5%, 5%. (Morrow, 1984, personal communication).

Column (5): Makinen (1982) and Shepard, Sanoh and Coffi (1982a) have estimated the effectiveness of measles vaccine under field conditions in Cameroun and the Ivory Coast at 48.5% and 60% respectively. The second and more optimistic figure is used here. The other effectiveness proportions are conjectured to be obtainable in a well-managed EPI system.

Column (6): Column (5) x column (4). The diptheria, pertussis and non-neonatal tetanus vaccines are administered in a single vaccine called "DPT."

Column (7): The eight distinct applications of a vaccine to a "fully immunized" individual are: one each of measles and BCG, three of polio and three of DPT. The theoretical distribution of vaccinations across these eight distinct vaccination events is based on the calculations by P. Knebel of the Sahel Development Planning Team, Bamako, Mali as presented in Agency for International Development (1983). It assumes that all children receive all six vaccinations.

Column (8): This distribution of vaccination types can be deduced from the data presented by Sanoh (1983) on aggregate vaccinations performed in the Abengourou region in 1981 and on estimated coverage of this rural population by each of the eight vaccination events.

Table 2. Estimation of Life-Days Saved Per Year in a Population of 50,000 in Rural Java When an Immunization Program is Added to an Existing Health Center.

	Without Immunization				With Immunization			
Age Group (1)	Pop. in Thous (2)	Life Expect. (3)	Death Rate (4)	Disa-bility Rate (5)	Death Rate (6)	Disa-bility Rate (7)	Life-Years Saved (8)	Thousands Days Saved (9)
0-1 Years Old	1.5	48	104.0	*	85.9	*	1301	*
1-4 Years	7.0	52	28.3	21.0	27.4	19.9	298	22.5
5-14 Years	13.0	50	2.7	*	2.4	*	176	*
15-44 Years	21.5	35	5.6	3.6	5.6	3.6	15	0.0
45 Years Old and Older	7.0	15	*	5.5	*	5.5	*	0.0
TOTALS	50.0		11.0	11.4	10.23	10.9	1790	22.5

SOURCE: Unless otherwise indicated, all references to pages, tables or appendices in the following notes are to R.N. Grosse, J.L.deVries, R.L.Tilden, A.Dievler,S.R.Day, "A Health Development Model Application to Rural Java," Final Report of Grant No. AID/otr-G-1651, Department of Health Planning and Administration, School of Public Health, University of Michigan, October, 1979.

NOTES: Immunization program consists of 27,000 shots per year against tuberculosis (6600 doses BCG vaccine), diptheria, pertussis, and both neonatal and postnatal tetanos (18300 doses DPT vaccine plus 2100 doses tetanos toxoid), but excludes measles. See pages 30, 34 and pages 2 and 3 of Appendix A in Grosse et al.

Column (2): From page 27 and page 20 of Appendix I.

Column (3): Interpolated by author from Ghana Health Assessment Team (1981, Table A).

Column (4): Deaths per thousand population from base run with a health center but no additional health programs. See alternative 1, PV 1 in the first line of Table 7 on page 47 or of any table in Appendix F. Since these tables do not provide the mortality rates of for the two groups over 15, an overall rate for both groups is interpolated.

Column (5): Days of disability per person per year. Source is same as column (4) except interpolation is required for those under 15.

Column (6): From Table 7, alternative 1, PV 3 with interpolation as for column (4).

Column (7): Same as (6) with interpolation as in (5).

Column (8): Using C4 to represent column (4), etc. the formula for this column is:

C2 x C3 x (C4 - C6).

The fifth row uses a population of 28.5 and a life expectancy of 30.

Column (9): Thousands of days of disability saved per year computed by:

C2 x (C5 - C7).

First, consider the number of additional life years that would be saved if measles vaccination were added to the Javanese program. The Michigan study estimated the incidence rate at zero for infants less than one and only 200 per thousand among children aged one to four. In the latter group the study assumed the case fatality rate to be 4.8% (0.5% among the 20% treated and 5% among the 80% untreated). If measles vaccine is 60% effective as assumed in Table 1, then it will save 5.76 lives per thousand vaccinated (200 x .048 x .6). Assuming that 1,500 children are vaccinated per year just as they are entering the 1-4 age bracket where their life-expectancy is 52 years (from Table 2, column 3), the addition of measles vaccination would save an additional 449 life years per year in this Javanese rural population of 50,000 (5.76 x 1.5 x 52).

However, the incidence of neonatal tetanus in Java was estimated at 21.3 per thousand with a case fatality rate of 90%. Thus, removing the 2100 doses of tetanus toxoid given to the pregnant mothers (assumed 95% effective by Grosse et al, Appendix A, p.3) would increase deaths in the zero to one age group by 18.2 per thousand. For the 1,500 in this age group whose life expectancy is 48 years, the life-years lost would be 1,310 (18.2 x 1.5 x 48).

The Michigan study did not include polio among the 31 diseases analyzed, possibly because its impact on mortality and morbidity was deemed small. Indeed in Ghana polio does not even rank among the top 25 contributors to life-days-lost (Ghana Health Assessment Team, 1981, Table 2). As a rough approximation, assume that the Ghanaian figure of 1.2 days of life lost per person per year applies to Java as well. Then adding polio vaccination would save an additional 164 life years in the population of 50,000 Javanese (1.2 x 50,000 / 365.25), while requiring an additional 18,300 vaccinations on the assumption that the children getting DPT get polio vaccinations at the same time.

Thus the net effect of these three adjustments to the Javanese immunization program would be a loss of 697 life-years (449 + 164 - 1310) and an increase in the number of vaccinations by 17,700 (1500 + 18,300 - 2100). To arrive at an estimate of b for Java, subtract 697 from 1790, multiply the result by the number of days in a year and add 22,500 days of averted disability (from column 9 of Table 2) for a total of 421,700 LDS. Then divide this total by the 44,700 (27,000 + 17,700) vaccinations that would be required to achieve it. The resulting estimate is 9.4, a substantial reduction in average impact from the program defined by the Michigan study.[15]

2. Estimates of Life-Days-Saved Per Encounter. The impact of an immunization program is inherently easier to estimate than that of a VHW program, because effective immunization produces a measureable change in blood chemistry which accurately predicts whether an individual will ever contract the disease in question. In some cases sero-conversion correlates highly with an even more visible sign, a scar at the vaccination site. In contrast, the impact of VHWs on health can only be measured by observing a change in health status associated with their activites. Nevertheless the absence of information on the impact of VHW services on health status is surprising in light of the available experience with VHW projects. A review published in 1982, which limited itself to primary health care projects funded by the United States Agency for International Development, identified 52 such projects of which 42 used a VHW of one variety or another. However, the reviewers could find only "only five evaluations of health status located in

the project documents reviewed" (American Public Health Association, 1982, p. 81). One of these was for a project without VHWs. Two of the other four cited evidence of positive impacts of VHW activities on health status and the other two demonstrated no significant effect. Although "nearly all the projects plan to evaluate outcome by measuring changes in health status, . . . many evaluation components are initiated but never completed ; others are executed late; and still others are never initiated" (ibid., pp. 79, 80).

As a result of this lack of information on the effectiveness of VHW activity, any estimate of a, the number of life-days-saved per VHW encounter, must be proposed even more tentatively than the estimates of b, above. However, by using expert judgements of VHW effectiveness, two independent estimates of a are possible, one from Ghanaian and the other from Javanese data and assumptions. Table 3 develops estimates of the number of life-days saved per VHW encounter based on primarily Ghanaian rough estimates of the effectiveness of the Ghanaian VHW at treating 13 different disease categories. Column (6) gives an estimate of the number of "needed" encounters with a VHW per year, assuming that all of this need generates effective demand by villagers for treatment outside the home and that no traditional healers, pharmacists or other providers substitute for the VHW. Based on this undoubtedly high estimate of encounters per year, column (7) computes the average number of LDS per encounter to be 14.9.

The extent to which demand for the services of a VHW will fall short of "need" is difficult to estimate until a study such as those of Heller (1982) and Mwabu (1983) on Kenya is available for VHWs in a country similar to that under consideration. Column (8) of Table (3) gives a rough estimate of such demand based on the assumption that the villagers will not accept any preventive or screening services from the VHW and that they do not demand "enough" care from the VHW for colds, diarrhea, schistosomiasis and childhood pneumonia, because they seek other sources of care or because they consider these symptoms to be insufficiently serious to warrant treatment. (It has been reported that blood in the urine, a symptom of schistosomiasis, is considered to be a mark of manhood in some cultures.) These assumptions reduce by half the total number of encounters by the VHW, but reduce the number of LDS by three-quarters so that the average LDS per encounter also drops by half to about 7.5, still a substantial number even under these admittedly pessimistic assumptions.

While the Ghanaian analysts computed total life-days lost under the current health system for 48 diseases and the impact that VHWs could be hoped to have on nine of those, the Michigan study considered each of only 31 diseases at a much more disaggregated level. Working from estimates of the incidence of each of these 31 diseases for each of six age-sex categories under each of eight different combinations of immunization, sanitation and nutrition programs, the Michigan study developed estimates of the impact of the VHWs and of five other treatment combinations on mortality and morbidity in the rural Javanese population of 50,000.

Table 4 extracts from this work the information necessary to estimate the number of LDS per VHW encounter in Java. Converting the estimated number of life-years saved from column (8) to days and adding the number of disability days from column (9) gives a total savings of 3,531,200 LDS. Dividing this total by the estimated number of encounters of 235,000 gives an estimated number of LDS per encounter of 15.0.

Table 3. Estimation of the Average Number of Life-Days Saved Per Encounter with a Village Health Worker.

Disease (1)	Life-Days Lost If Sick (2)	VHW Effectiv-ness (3)	Life-Days Saved/ Encntr (4)	Incidence Per Thou. (5)	Est'ed "Need" (6)	Life-Days Svd. (7)	Est'ed "Demand" (8)	Life-Days Saved (9)
1. Cold	0.6	0.10*	0.04	1000.0	1600	0.02	800	0.02
2. Skin Infection	6	0.10*	0.4	470.0	752	0.09	752	0.17
3. Malaria	815	0.26	29.3	40.0	289	2.58	0	0.00
4. Malnutrition, Severe	11667	0.63	1016.8	1.5	11	3.40	0	0.00
5. Gastro-enteritis	207	0.38	49.2	70.0	112	1.68	56	1.68
6. Accidents	1935	0.20*	241.9	7.7	12	0.91	12	1.82
7. Schisto-somiasis	629	0.69	271.3	7.0	11	0.92	6	0.93
8. Pneumonia - Child	7750	0.37	1792.2	2.4	4	2.09	2	2.10
9. Pneumonia - Adult	1300	0.15	121.9	7.0	11	0.42	11	0.83
10. Premature Birth	1750	0.10	18.7	9.6	90	0.51	0	0.00
11. Complications of Pregnancy	1229	0.39	51.1	4.8	45	0.70	0	0.00
12. Birth Injury	10250	0.21	229.6	1.6	15	1.05	0	0.00
13. Other Diseases	786	0.01*	4.9	209.0	334	0.50	0	0.00
TOTALS	38,325			1,830.6	3,287	14.86	1,639	7.53

NOTES: Column (2): Derived by dividing the life-days-lost calculated by the Ghana Health Assesment Project (1981) by the estimated incidence rate from column (5).

Column (3): The National Health Planning Unit (1978, Table 6) of Ghana estimated healthy days of life currently lost from each disease, LDL, the life days that would be saved by the fully implemented primary health care system including VHWs, LDS, and the portion of these savings that would be achieved without the VHW system, LDS†. Figures without asterisks are derived by the formula: (LDS-LDS†)/(LDL-LDS†). Figures with asterisks are the author's estimates for diseases omitted in the National Health Planning Unit document.

Column (4): Column (2) x Column (3) divided by an estimate of number of encounters per episode, which is given by the ratio of column (6) to column (5).

Column (5): From Ghana Health Assessment Project (1981).

Column (6): Prevention of malaria and malnutrition on the one hand and birth problems on the other requires frequent encouters (e.g. five per year) between the VHW and the target groups of children under three and pregnant women respectively. Assuming there are 60 children under three and 30 pregnant women per thousand population, the two groups would require 300 encounters and 150 encounters respectively. These totals are distributed across diseases 3 and 4 on the one hand and diseases 10, 11 and 12 on the other according to the incidence ratios. Other diseases are assumed to average 1.6 encounters per episode, the ratio observed in a sample of VHW huts in Senegal in 1979 (Over, 1980).

Column (7): Column (4) x Column (6) divided by the sum of Column (6).

Column (8): Assume the VHW performs no preventitive or screening services and, for lack of demand, sees only half the episodes of diseases 1, 5, 7 and 8.

Column (9): Column (4) x Column (8) divided by the sum of (8).

Table 4. Estimation of Life-Days Saved Per Year in a Population of 50,000 in Rural Java When 200 Village Health Workers are Added to an Existing Health Center.

	Without VHWs				With VHWs			
Age Group (1)	Pop. in Thous (2)	Life Expect. (3)	Death Rate (4)	Disa-bility Rate (5)	Death Rate (6)	Disa-bility Rate (7)	Life-Years Saved (8)	Thousands Days Saved (9)
0-1 Years Old	1.5	48	104.0	*	67.2	*	2647	*
1-4 Years	7	52	28.3	21.0	13.4	17.2	5424	81.4
5-14 Years	13	50	2.7	*	1.6	*	696	*
15-44 Years	21.5	35	5.6	3.6	4.6	3.2	639	9.2
45 Years Old and Older	7	15	*	5.5	*	4.7	*	5.3
TOTALS	50		11.0	11.4	6.9	9.4	9405	96.0

SOURCE: R.N. Grosse, J.L.deVries, R.L.Tilden, A.Dievler,S.R.Day, "A Health Development Model Applation to Rural Java," Final Report of Grant No. AID/otr-G-1651, Department of Health Planning and Administration, School of Public Health, University of Michigan, October, 1979.

NOTES: Village Health Worker Program as defined by Grosse et al (ibid., pp. 5-7 of Appendix D) consists of one VHW per 250 people (or per 50 households) handling 4.7 encounters per person per year, for a total of 235,000 encounters in the population of 50,000. Of the 31 disease categories included in their analysis, Grosse et al assume that treatment at a rural health center can have a beneficial effect on either morbidity or mortality in 20 of these, but that a VHW has some impact in every disease where the health center has an impact.

Columns (2) through (5): Repeated from Table 2, this paper.

Column (6): From Alternative 6, PV 1 the results of which are given on the eighth line from the bottom of page 4 of Appendix F of Grosse et al (1979). Interpolated as for column (4).

Columns (7) through (9): Same notes as for Table 2 this paper.

Unlike the estimate of need in column (7) of Table 3, the Michigan study explicitly incorporates assumptions on the proportion of cases in each age group for each disease that will seek treatment from the VHW (Grosse et al, Appendix B). These proportions range from .90 for severe diarrhea and upper respiratory infection down to .30 for intestinal parasites and .10 for complications of childbirth and pregancy. While some of these figures seem rather high, the fact that these adjustments have been made makes the Javanese estimate more comparable to the Ghanaian estimate based on "demand" than to that based on "need." Thus the Javanese estimate is twice as large as the comparable one for Ghana.

An examination of the the details of the Michigan study calculations reveal that they were more optimisitic than were the Ghanaian analysts regarding the productivity of the VHW. The Michigan analysts assumed the VHW would have some effect on mortality or morbidity for 20 of the 31 diseases analyzed, whereas the Ghanaian analysts hoped for such an impact on only nine diseases. Furthermore, for those problems which both studies assumed the VHW would influence, the Michigan study assumed a greater VHW effectiveness. Column (6) of Table 5 presents the implied effectiveness of the VHW in the Michigan study which compares most directly with each of the values from column (3) of Table 3. Setting aside colds and skin infections as not having been considered by Ghanaian analysts (and in any event of trivial consequence for total LDS), the column (6) effectiveness figure for Java is typically greater than the corresponding Ghanaian figure. These greater effectiveness estimates, together with the larger number of diseases the Javanese VHW is assumed to influence and the higher level of assumed demand combine to make the estimate of 15 LDS per encounter a relatively optimistic one. Nevertheless, it is encouraging that it is of the same order of magnitude as the estimate for Ghana.

3. Estimates of Parameters of the Cost Functions. Turning now to the right-hand-side of decision rule (9), consider the parameter μ_f. This parameter was defined in section III above as the ratio of two numbers. The denominator of this ratio is the number of vaccinations that a fixed center operating on budget C^* could deliver on site in one year, if it has no responsibility for VHW support and supervision. (In section III, this number was called V^*.) The numerator is the number of encounters that the same fixed center could support on the same budget through the supervision of outlying VHWs. To determine this number with any confidence will require detailed cost and management studies of fixed centers with outreach and VHW supervision activities in several developing countries.

However suppose that the cost (net of vaccine costs) of traveling to within reach of Q people is directly proportional to Q to the power s, where s is the degree of returns to scale in the cost function (and bears the same interpretation as the returns to scale parameter introduced in equation (2) of section III). Suppose the cost function is roughly the same whether the purpose of travel is to vaccinate the target group within Q by a mobile team or to supervise the VHWs who serve Q by a fixed center, provided that only one of these two tasks is performed. Under these assumptions, Table 6 develops an estimate of μ_f for each of several values of s based on preliminary estimates of the costs of a mobile vaccination team operating in Abengourou, Ivory Coast, in 1981 (Sanoh, 1983). [16]

Table 5. The Estimated Effectiveness of the Javanese VHW on the Twelve Disease Problems of Table 2 of the Text.

Ghanaian Disease Category (1)	Ghanaian Effec- tivness (2)	Ghanaian Incidence (3)	Javanese Disease Category (4)	Aggregated Javanese Age Group (5)	Percentage Improvement in Case Fatality Rate (6)	Javanese Incidence (7)
1. Cold	10%	1000	2. URI	0-15	0%	2000
				15+	0%	1000
2. Skin Inf.	10%	470	4. Skin Dis.	0-15	0%	50
				15+	0%	100
3. Malaria	26%	40	8. Malaria	0-15	96%	20
				15+	100%	50
4. Malnutrition	63%	1.5	not included			
5. Gastroenteritis	38%	70	5. Mild Diarrhea	0-15	0%	2000
				15+	0%	1000
			6. Severe Dia.	0-15	69%	250
				15+	40%	80
6. Accidents	20%	7.7	13. Burns	0-15	54%	30
				15+	0%	10
			14. Fractures	0-15	44%	1
				15+	29%	1
			15. Cuts	0-15	63%	15
				15+	70%	15
7. Schistosomiasis	69%	7	not included			
8. Pneumonia, Child	37%	2.4	1. LRI	0-15	79%	50
9. Pneumonia, Adult	15%	7	1. LRI	15+	79%	10
10. & 12. Prem. Brth & Birth Injury	10% 21%	9.6 1.6	21. Comp. Brth & Pregnancy	0-1	85%	90
11. Comp. of Preg.	39%	4.8	21. Comp. Brth	Wom. 15-44	21%	24

SOURCES: Grosse et al (1979), Ghana Health Assessment Team (1981) and Natiol Health Planning Unit (1978).

NOTES: Columns (2) and (3): From Table 2 in the text.

Column (3): Incidence per thousand in overall population from Table 1 of Ghana Health Assessment Team (1981).

Column (4): Appendix A of Grosse et al (1979).

Column (5): Aggregates of the six age-sex categories used in Appendices A and C of Grosse et al (1979).

Column (6): Calculated from the last two columns of Appendix C of Grosse et al (1979) by the formula (CFNRX-CFRX)/CFRX, where CFNRX is the case fataility rate without treatment, CFRX is the case fatality rate with treatment by a VHW.

Column (7): Derived from the incidence rates by age-sex group in Appendix A of Grosse et al by choosing a value in the middle of the range of incidence rates given in that source.

Table 6. Estimation of μ_f in Abengourou, Ivory Coast
Under Constant and Increasing Returns to Scale

	Constant Returns to Scale	Increasing Returns to Scale		
	(s=1.0)	(s=.9)	(s=.8)	(s=.7)
1. Population covered by VHWs attached to a single fixed center:	7,900	5,750	3,860	2,320
2. Number of fixed centers "needed" to serve the entire region of Abengourou:	17	24	36	60
3. Estimated number of encounters by VHWs attached to a single fixed center with budget given under Assumption F2 below (i.e. μ_f V^*):	37,100	27,000	18,200	10,900
4. Estimate of the parameter μ_f:	10.6	7.7	5.2	3.1

Data and Assumptions Used:

Abengourou Mobile Team:

M1. Estimated rural population of Abengourou:	138,000
M2. Total cost of mobile team for one year:	5,293,814
M3. Cost of vaccine:	1,009,600
M4. Cost to reach rural pop. w/o vaccinating:	4,284,210
M5. Average Cost per Cap to reach rural pop.:	31.0

Fixed Centers as VHW Supervisors:

F1. Number of vaccinations with no encounters, V^*:	3500
F2. Budget for V^* vaccinations, C^*:	735,700
F3. Assumed number of supervision trips per year to each VHW:	3
F4. Maximum cost per spvsn trip that stays within budget, C^*:	245,233
F5. Assumed number of encounters with VHW per capita per year:	4.7

NOTES: Row 1: Assume the simple model of transport and supervision cost $C = A\ Q^s$, where s is the returns to scale parameter with a similar interpretation to the s introduced in equation (2) of section III of the text, Q is the quantity of rural residents to whom the traveling health professionals come sufficiently close to either vaccinate almost all of the target group among them or to supervise the VHW who treats them, and C represents all costs except drugs and/or vaccines. Then the ratio of two values of Q is equal to the ratio of the two corresponding costs to the power 1/s. The entries in this row are thus equal to:

$$(\text{Item M1})\text{x}(\text{Item F4}/\text{Item M4})^{(1/s)}$$

Row 2: Item M1/Row 1.
Row 3: Row 1 x Item F5.
Row 4: Row 3/Item F1.
Item M1: The rural population is estimated at about 69% of the total population of Abengourou given by Sanoh as 200,000 in 1981.
Items M2, M3, M4 are from Table 3 of a draft final report on a cost-effectiveness study by L. Sanoh of CIRES, Abidjan and the Boston University Strengthening Health Delivery Services Project, and are measured in 1981 CFA francs. (Approx. 260 CFA francs/dollar in 1981). (Sanoh, 1983)
Item M5: Item M4/item M1.
(Notes continued on next page.)

Suppose $s=1$, implying constant returns to scale in transport. Then the assumptions of Table 6 yield an estimate of μ_f equal to 10.6. If on the other hand the mobile team achieves substantial economies of scale in transport that would not be available for smaller amounts of travel by a VHW supervisor attached to a fixed center, then the value of μ_f is estimated to be as low as 3.1 when $s = 0.7$. At this value of s, total transport costs rise only seven percent for every ten percent increase in Q. If the commercial trucking industry in an LDC benefited from economies of scale as great as this, one would not expect to find any small independent truckers left in the country.

According to the decision rule, if b/a is greater than the ratio of μ_f to a function of β (or of σ), Strategy M is more cost-effective than Strategy F. However, the function of β varies between one (when β approaches infinity) and two (when β approaches one). Thus if b/a is greater than μ_f, or less than $\mu_f/2$, the value of β has no effect on the decision. In the former case, Strategy M is more cost-effective and in the latter case Strategy F dominates. Only if b/a is between these two bounds is β important.

4. Applications of the Decision Rule. Table 7 presents four estimates of b/a across the top and four estimates of μ_f down the left side. The cells of the table are divided into three sections by dotted lines. Cells to the northwest, where b/a is less than $\mu_f/2$, are marked with an F to indicate that these parameter values lead to the choice of Strategy F regardless of the degree of complementarity of the fixed center cost function. Cells to the southeast contain an M to indicate the reverse. Only in the cells between the two dotted lines does the strategy choice depend on the value of β. Instead of an F or an M, these cells contain the critical value of β (and in parentheses the critical value of σ) above which (below which) the decision rule would prescribe Strategy F.

For reasons explained above, column (2) for Java and column (4) for Ghana seem more plausible than columns (1) and (3) respectively. Also constant or only mildly increasing returns to scale, as represented by rows (A) and (B) seem more plausible than the more extreme economies of scale as represented by rows (C) and (D). Within these cells, Strategy F unequivocally dominates Strategy M in Java, regardless of the complementarity in the Javanese fixed centers.

NOTES TO TABLE 6 (continued):

Item F1: The average number of vaccinations per year performed by the two of the fourteen rural fixed health centers in Abengourou which perform such vaccinations as reported by Sanoh (1983, Table 6).

Item F2: The average total cost for producing these vaccinations. (Sanoh, 1983, Table 3).

Item F3: In West African VHW worker projects, 3 supervisions per year is a minimum recommendation. See for example Over (1980, 1982).

Item F4: Item F2/item F3.

Item F5: The assumption used in Grosse et al (1979). At one VHW per 500 inhabitants, this figure implies 45 encounters per week. In a sample of nine Senegalese villages visited in the summer of 1979, Over (1980) found the average VHW was seeing 6.5 villagers a day, with a standard deviation of 3.9. This small sample thus supports the estimate from Grosse et al.

However, for Ghanaian assumptions on the health impacts of vaccinations and encounters, the degree of complementarity plays an important role. If e and v can be produced as perfect joint products so that the isocost curve looks like Figure 1d, then ß is very large (σ approaches zero) and Strategy F is preferable for $s \geq .9$. If, on the other hand, the opportunity cost of supervising VHWs from a fixed center is substantial in terms of foregone vaccinations so that the Strategy F isocost curve resembles Figure 1a, then ß approaches one (σ approaches infinity) and Strategy M is preferable for $s \leq 1.0$.

Based on these illustrative parameter estimates, the choice of primary health care integration strategy seems to be quite sensitive to the particularities of the epidemiological situation and the costs of production in a specific region. Where the relative impacts of vaccination and basic health services and the relative costs of the two strategies resemble the West African data and assumptions used to generate rows (A) and (B) of column (4), the degree of complementarity of the joint production of vaccinations and encounters in fixed centers is an important input to the strategy choice.

V. Concluding Remarks

With only two parameters for the objective function and three from each cost function, the model presented here is extremely parsimonious. The advantages of this parsimony are that the coefficients of the model are relatively easy to estimate and that the model can be relatively easily understood by decision-makers. Of course, the parsimony is purchased at the expense of several strong assumptions. Most important among these is the assumption that the choice between the fixed and mobile integration strategies is the important policy decision and is separable from other government policies and programs within and without the health sector. A second critical assumption is that the units of analysis can be the "average encounter" and the "average vaccination" and that the chosen integration strategy is independent of the mix or impacts of these average events. A third assumption is that the national health objective in rural areas is to maximize healthy-life-days.

Given these assumptions and the additional assumption that the effects of diseases and health interventions are additive, the parameters of the objective function can be "guess-timated" from fundamental epidemiological data organized according to the pattern of the Ghana Health Assessment Team study, as is done here in Tables 1 and 3. Since each of the objective function parameters (a and b) represents the net impact of an intervention on an index of overall health status, rather than its impact on any single disease, it would be feasible to estimate the objective function for a region by setting up two experimental groups, one with only the vaccination program and

Table 7. Cost-Effective Choice of an Integration Strategy for Various Parameter Estimates

Estimates of the Average Impact on Healthy Life Days of:	Java with EPI (1)	Java Orig. Assum. (2)	Ghana Theory (3)	Ghana Demand/ Obsrvd (4)
A vaccination (parameter b)	9.4	25.0	75.4	53.8
A VHW encounter (parameter a)	15.0	15.0	14.9	7.5
Ratio of b/a:	.6	1.7	5.1	7.2
Cost Function Parameters s and μ_f:				
Constant Returns to Scale:				
(A) For s = 1, μ_f = 10.6	F	F	F	3.2 (0.5)
Increasing Returns to Scale:				
(B) For s = 0.9, μ_f = 7.7	F	F	2.9 (0.5)	20.3 (0.05)
(C) For s = 0.8, μ_f = 5.2	F	F	71.2 (0.01)	M
(D) For s = 0.7, μ_f = 3.1	F	1.7 (1.4)	M	M

NOTES: Column (1): The estimate of b is derived in the text. The estimate of a is based on Table 4.

Column (2): The estimate of b is based on Table 2, that of a on Table 4.

Columns (3) and (4): The estimates of b and a are from Tables 1 and 3.

Rows (A) throough (D): The estimates of μ_f are from Table 6. The numerical entries in cells A4, B3, B4, C3 and D2 are the values of ß which solve the equation:

$$\frac{b}{a} = \frac{\mu_f}{\left(2^{[\beta/(\beta-1)]}-1\right)^{(\beta-1)/\beta}}$$

The values in parentheses are the values of the elasticity of complementarity, defined as $\sigma = 1/(\beta-1)$. In these cells, if ß is above the specified value (or if σ is below the specified value in parentheses) then Strategy F is the cost-effective choice. Otherwise Strategy M is the cost-effective choice.

one with only the VHWs, and measuring the impact of each intervention on health status relative to a control group where neither intervention is introduced.[17] Alternatively and less satisfactorily, the parameters a and b could be estimated at relatively little cost by multiple regression on nonexperimental data from the region of interest. Either of these estimation techniques has the additional advantage over "guess-timation" of correcting for the problems of disease interdependence and competing risk, and thus allowing relaxation of the unpalatable assumption that health effects are additive.

The cost function parameters could be "guess-timated" in a specific country by working with experienced health ministry managers and depending on their judgement as to the costs of various combinations of activities.[18] Here too it would be feasible and preferable to estimate these parameters statistically using a sample of mobile teams and fixed centers that are performing some or all of the vaccination and VHW supervision functions. With enough observations, a more flexible functional form could be chosen in lieu of the constant elasticity form used here. With increased flexibility, changes in average unit cost could be attributed to changes in coverage and intensity as well as to changes in output mix as modeled here. [19]

It is useful to contrast the present study with two other cost-effectiveness studies of primary health care in developing countries, both of which were led by economists from the University of Michigan. A team based at the School of Public Health constructed the linear-programming model referenced in Tables 2 and 4 above, which depends on 3,696 different parameters in place of the two parameters in the objective function used here (Grosse et al, 1979, Appendices A, B and C). Although the SPH model deals with separate packages of interventions as discrete administrative entities - just as the present paper treats Strategy F and Strategy M as distinct - the SPH model is completely linear and thus would require modification to address the problem of strategy choice with joint costs.

An independent team based at Michigan's Center for Research on Economic Development constructed a programming model which has a non-linear objective function, but linear cost constraints (Barnum et al, 1980). Although more parsimonious than the SPH model, the CRED model nevertheless includes 221 parameters. With modification to incorporate nonlinear cost constraints, this model could also be used to address the strategy choice problem.

Given the available computer time and resources, models patterned after the SPH and CRED models would be useful tools for health planners in developing countries to address almost any health planning problem. However, the size and complexity of these models makes them costly and unwieldy and may reduce the degree to which they are understood, believed and used by decisionmakers. Until these models are generally available, understood and believed, smaller, special purpose models such as the present one may play an important role in guiding policy decisions and generating demand among decision-makers for modelling exercises.

A consideration which is difficult to introduce explicitly into the model, but must be addressed in the choice of primary health care integration strategy is the degree of uncertainty in the present about various aspects of the future. Two variables are particularly importanc in this regard and act in opposite directions on the preferrred strategy choice.

First, suppose there is uncertainty regarding the population likely to inhabit the region under consideration in five or ten years. Even if fixed centers appear optimal given today's estimates of cost and health impact parameters, creating them may be unjustified if a large proportion of the population might migrate either out of the region or to new population centers within the region. In this situation the flexibility of the mobile teams is a substantial argument in their favor.

A second dimension of uncertainty is the regional rural health budget constraint. If this budget is often cut markedly from programmed levels, then the effect on healthy-life-days of operating both strategies at this much lower level of funding must be considered. The best strategy in this situation is the one that saves the most healthy-life-days over a series of years when the budget varies back and forth at random from its full level to its lowest level. Even if the mobile strategy seems best based on the model presented here and the assumption of full funding, its absolute need for fuel may make its productivity much more sensitive to recurrent cost crises than would be the fixed center, and thus the less preferred option when such crises are considered likely.

In view of the tentativeness of the Section IV estimates, the need for research is evident. But which parameters should be the focus of priority efforts? Which parameter estimates would provide the greatest benefit at the least cost?

The benefits of immunization, represented here by the parameter b, are the best known portion of the model and of the data, so they are not at the top of the list of research priorities. As discussed in Section IV, the benefits of VHW services are less well-understood, and thus in greater need of research effort. However, the statistical and political problems inherent in estimating these benefits are immense. This research is necessary, but must proceed deliberately, without the expectation of a quick payoff. In contrast to these two areas, research on the joint cost function for multiple primary health care services in rural areas is both lacking and relatively easy to perform. Thus the top research priority in the health sector of developing countries should be estimation of a set of these cost functions, so that planning models can better serve as practical guides to policy.

NOTES

[1] While an LDC might choose Strategy F in one region of the country and Strategy M in another region, it is hard to see how a combination of both strategies could be implemented cost-effectively in the same region, because such a mixture of strategies would require the MOH to provide expensive transport and management time to reach each village more often than would otherwise be necessary.

[2] One argument for different weights is that adding healthy-life-days to the life of a productively employed adult may save additional life-days of his or her dependents. The political sensitivity of such relative weights is an argument for establishing them within the decision-making apparatus of the country in question.

[3] For some purposes it would be desirable to disaggregate further among consultations for different preventive and curative problems. Such a further disaggregation is a straightforward generalization of the three-fold disaggregation presented here. Over and Smith (1980) and Smith and Over (1981) present an approach to the creation of homogeneous aggregates of patient problems in an ambulatory setting.

[4] To the extent that the initial investment cost and the eventual replacement cost of the project's capital have a positive opportunity cost to the country, the relevant cost constraint for the planner includes the value of all these capital expenses plus the value of all discounted future recurrent expenses. Then it would be necessary to modify the objective function to capture the stream of all future healthy-life-days, also discounted to the present. However, donors frequently make funds available for the investment costs of health projects which are not available for other expenditures in the same country. Furthermore, many developing countries behave as if replacement capital will be provided by donors, an expectation that has often been fulfilled. The assumption here is that the opportunity cost of capital expenditures is zero so that the only relevant cost constraint for the developing country is the recurrent cost function. This assumption makes every year the same so that the intertemporal aspect of the problem can be ignored and there is no need to discount future capital expenditures or future healthy-life-days. See Gray and Martens (1980) and Over (1980) on the recurrent cost problem in LDCs.

[5] Although not derived from profit maximizing assumptions, these cost functions represent best sustainable managerial practice and thus should be estimated by the technique developed for "frontier production functions". If the production technology is defined for only a limited number of discrete points in the space spanned by vectors $\underline{e}$ and $\underline{v}$, then a continuous curve fitted to these points may be inappropriate. The integer-programming approach that must be turned to in this situation can, of course, capture joint production and other nonlinearities. For an example of the representation of a nonlinear production technology by a piece-wise linear integer-programming model in health, see Smith and Over (1981).

[6] The problem of joint cost allocation raises its head again if there is jointness in the production of $\underline{e}$ and $\underline{v}$ with <u>other</u> health sector activities (such as the other activities of the fixed centers). If the amount of total recurrent costs incurred jointly in the production of these other activities with $\underline{e}$ and $\underline{v}$ is small

then standard allocation rules can be used as suggested in de Feranti (1983, pp. 31-33). However if joint costs are so large that different allocation rules alter the choice between the fixed and mobile strategy, then the scope of the model must be expanded to include a vector of these other activities in the objective function as well as in the cost functions.

[7] In fact $h(\underline{e}, \underline{v}, \underline{x})$ is likely to be nonlinear both because the health impact of any given intervention typically diminishes with increased coverage or intensity and because a reduction in the morbidity or mortality from one disease typically influences the morbidity and mortality from other diseases. Barnum et al (1980, Chapters 2, 3) specify a programming model with a nonlinear objective function to capture these problems, though for lack of appropriate data they are forced to estimate its 221 parameters from the survey responses of 16 experts. Section V and its notes discuss a nonlinear version of $h(\underline{e}, \underline{v}, \underline{x})$ in the present model.

[8] The functional form of equation (2) is that of the constant elasticity of substitution production function with the sign of its exponent, and thus its curvature, reversed. The elasticity of product transformation (or elasticity of complementarity) is given by $\sigma = 1/(\beta - 1)$ and can be interpreted as the percentage increase in the optimal ratio of vaccinations to encounters (v/e) resulting from a one percent increase in the ratio of the effectiveness of vaccinations to that of encounters (b/a). By assumption the cost function is separable in prices and output.

[9] Under this hypothesis:

$$V^* = [\, C^*/A_f(\underline{\beta})\,]^{(1/s_f)} = .5\,[\, C^*/A_m(\underline{\beta})\,]^{(1/s_m)}$$

Thus for given $\underline{\beta}$, $A_f(\underline{\beta})$, $A_m(\underline{\beta})$, s_f and s_m, V^* is an increasing function of C^*. Under constant returns to scale $A_f(\underline{\beta}) = 2\,A_m(\underline{\beta})$ and $V^* = C^*/A_f(\underline{\beta})$.

[10] For example, Walker and Gish (1977) found mobile services to be substantially less cost-effective than fixed services at the delivery of curative care.

[11] See note 9.

[12] The assumption of complementarity in the Strategy M production process would likewise render that strategy more competitive.

[13] The Ghana Health Assessment Team presents estimates of total healthy-life-days-lost due to each disease.(1981, Tables 1, 2) Whether measured by age- and disease-specific mortality rates or by healthy-life-days-lost in the population, the total burden of a disease on society cannot be used directly to prioritize disease interventions. Instead it is necessary to estimate the marginal number of life-days-saved by an intervention and its marginal cost and then allocate resources so that the number of life-days-saved per unit cost is equalized across all interventions. (ibid., pp. 76, 77; Creese, 1979, pp. 24, 25). Tables 1 and 3 of this paper provide examples of possible approaches to translating the healthy-days-of-life-lost estimates from Ghana into impact measures of this sort.

[14] The programming model of rural primary health care in developing countries by Barnum et al (1980) has the advantage of modeling disease interdependence.

However, estimates of the parameters a and b cannot be easily deduced from the results reported for that model.

[15] Assuming the costs of this revised program would be larger than that of the program analyzed by Michigan, the smaller total LDS would make it less cost-effective than a program like that analyzed for Ghana. However, the low incidence of measles assumed by the Michigan study for unvaccinated Javanese children would have to be carefully substantiated.

[16] All figures drawn from Sanoh (1983) are preliminary and, like the other figures presented here, are for illustrative purposes only.

[17] With the addition of one more experimental group, one receiving both vaccination and VHW services, an interaction term could be introduced into the objective function. Equation (1) of the model would then be modified to read:

$$H = h_0 + a\,e + b\,v + d\,e\,v\,.$$

A new version of decision rule (9) would then have to be derived accordingly.

[18] Two modifications of Creese's (1979) costing guidelines would be helpful. The unit of analysis should be changed from the "fully-immunized-child" to the healthy-life-day and procedures should be suggested for allowing encounters and vaccinations to be treated as joint products.

[19] For example, Chiang and Friedlander (1984) use a translog function to specify a general multiproduct cost function.

REFERENCES

Agency for International Development (1983) "Project Paper for the Rural Medical Services Project in Mauritania," mimeo., Noaukchott, Mauritania: USAID Mission.

Barnum, Howard, Robin Barlow, Luis Fajardo, Alberto Pradilla (1980) A Resource Allocation Model for Child Survival, Cambridge, Massacusetts: Oelgeschlager, Gunn & Hain.

Berggren, W.L., D.C. Ewbank, G.G. Berggren (1981) "Reduction of Mortality in Rural Haiti through a Primary-Health-Care Program," New England Journal of Medecine, Vol. 304, pp. 1324-30.

Chiang, S. Judy Wang, Ann F. Friedlander (1984) "Output Measurement, Network Effects, and the Measurement of Trucking Technology," The Review of Economics and Statistics, Vol. LXVI, No. 2, pp. 267-276.

Creese, Andrew L. (1979) "Expanded Programme on Immunization: Costing Guidelines," WHO Report EPI/GEN/79/5, Geneva: World Health Organization.

de Feranti, David (1983) "Some Current Methodological Issues in Health Sector and Project Analysis," mimeo., Population Health and Nutrition Department, World Bank.

Evans, J.R., K.L. Hall and J. Warford (1981) "Health Care in the Developing World: Problems of Scarcity and Choice,"New England Journal of Medicine, Vol. 305, pp. 1117-27.

Ghana Health Assessment Project Team (1981) "A Quantitative Method of Assessing the Health Impact of Different Diseases in Less Developed Countries," International Journal of Epidemiology, Vol 10, pp. 73-80.

Gray, C. and A. Martens(1980)"The Recurrent Costs of Development Programs in Sahelian Countries: Analysis and Recommendations," mimeo., Ouagadougou: Comité Inter-Etats de Lutte contre la Secheresse dans le Sahel; Paris: Club du Sahel; Cambridge, MA: Harvard Institute for International Development.

Grosse, Robert N., Jan L. deVries, Robert L. Tilden, Anne Dievler, Suzanne Rie Day (1979) "A Health Development Model Application to Rural Java," Final Report of Grant No. AID/otr-G-1651 from the Bureau for Program Policy and Coordination, United States Agency for International Development, Ann Arbor: Department of Health Planning and Administration, School of Public Health, University of Michigan.

Gwatkin, Davidson R. (1983) "Does Better Health Produce Greater Wealth?: A Review of the Evidence Concerning Health, Nutrition and Output," Mimeographed report. New York: Overseas Development Council

Gwatkin, D.R., J.R. Wilcox, J.D. Wray (1980) Can Health and Nutrition Projects Make a Difference, Monograph No. 13, Overseas Development Council, Washington, D.C..

Heller, Peter (1982) "A Model of Demand for Medical and Health Services in West Malaysia," Social Science and Medecine, Volume 16.

Kasongo Project Team (1981) "Influence of Measles Vaccination on Survival Patterns of 7-35 Month-Old Children in Kasongo, Zaire," Lancet, April 4, pp. 764-767.

Kielmann, Taylor, Desweemer, Uberoi, Takulia, Masih Vohra (no date) The Narangwal Experiment on Interactions of Nutrition and Infections: II Morbidity and Mortality Effects, supported by the Indian Council of Medical Research, WHO-H9/181/23.

Klarman, Herbert E. (1982) "The Road to Cost-Effectiveness Analysis," Milbank Memorial Fund Quarterly: Health and Society, Vol. 60, No. 4, pp. 585-603.

Mahieu, J.M. (1977) "Expanded Program on Immunization: Study of the Feasibility, Coverage and Cost of Maintenance Immunization for Children by District Mobile Teams in Kenya," Weekly Epidemiological Record, Vol. 52, No. 24, pp. 197-199.

Makinen, Marty (1981) "A Benefit-Cost Analysis of Measles Vaccinations in Yaoundé, Cameroun," Discussion Paper No. 96, Center for Research on Economic Development, University of Michigan, Ann Arbor,Michigan.

Mwabu, G. (1983) "A Household's Demand for Health Services: A Study of Rural Health Care with Emphasis on Kenya",Doctoral dissertation in economics, Boston University.

National Health Planning Unit (1978) "A Primary Health Care Strategy for Ghana," Republic of Ghana, Ministry of Health, National Health Planning Unit, Revised April 1, 1978.

Over, A. M., Jr. (1980) "Five Primary Health Care Projects in the Sahel and the Issue of Recurrent Costs," Mimeographed consultant report to Harvard Institute for International Development for the Sahel Recurrent Cost Study

Over, A. M., Jr. (1982) "Two Approaches to Projecting the Effect of Scale on the Cost of a Primary Health Care Program in a Developing Country: The Case of Niger," Presence Africaine, No. 124 (4th Quarter).

Over,A.M., Jr. (1983) "On the Care and Feeding of a Gift Horse:The Recurrent Cost Problem as the Result of Biased Project Design," Working Paper No. 69, African Studies Center, Boston University.

Over, A.M., Jr., K.R. Smith (1980) "The Estimation of the Ambulatory Medical Care Technology where Output is an Unobservable Variable," Journal of Econometrics, Vol. 13, pp. 225-251.

Parlato, Margaret Burns, Michael N. Favin (1982) Primary Health Care: Progress and Problems: An Analysis of 52 AID-Assisted Projects, Washington, D.C.: American Public Health Association

Sanoh, Layes (1983) Draft of a cost-effectiveness analysis of the expanded program of immunization in the Ivory Coast and personal communication with the author.

Scrimshaw, N., Taylor and Gordon (1968) Interactions of Nutrition and Infection, Geneva: World Health Organization.

Shepard, D.S., L. Sanoh and E. Coffi (1982a) "Estimating the Effectiveness of Measles Vaccination from Retrospective Household Surveys: Method and Preliminary Application to Rural Zones in the Ivory Coast," Project for Stengthening Health Delivery Systems, Boston University and Center for the Analysis of Health Practices, Harvard School of Health, September.

Shepard, D.S., L. Sanoh and E. Coffi (1982b) "The Cost-Effectiveness of the Expanded Program of Immunization: A Preliminary Report," Project for Stengthening Health Delivery Systems, Boston University and Center for the Analysis of Health Practices, Harvard School of Public Health, September.

Smith, K.R. and A.M. Over, Jr. (1981) "The Effect of Health Manpower Regulations on Productivity in Medical Practices," in Cowing and Stevenson (eds.) Productivity Measurement in Regulated Industry, Academic Press, New York.

Walker, G. and O. Gish (1977) "Mobile Health Services: A Study in Cost-Effectiveness," Medical Care, April, pp. 267-276.

World Health Organization (1978) "Alma Ata 1978: Primary Health Care: Report of the International Conference on Primary Health Care, Alma Ata, USSR, 6-12 September, 1978," World Health Organization, Geneva.

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