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A BENEFIT-COST ANALYSIS OF MEASLES

VACCINATIONS IN YAOUNDE, CAMEROON

by

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ABSTRACT

This paper discusses the issues involved in application of benefit-cost analysis to health programs and suggests some new approaches to them. The method developed is applied to the case of measles vaccinations given in Yaounde, Cameroon in 1971-1976. The results show that high benefit-cost ratios are obtained under the most conservative assumptions. Further, it is shown that giving more vaccination could have earned an even greater return. A Reed-Frost epidemiological model is used to find spillover benefits to vaccinations. A herd immunity level of 59 percent of the 6-26 months population is found.

SOMMAIRE

Ce document examine les problèmes associés à l'application d'une analyse coût-avantages aux programmes sanitaires et propose quelques approches innovatrices. La méthode développée est appliquée aux cas de vaccinations contre la rougeole administrées à Yaoundé, au Cameroun, en 1971-1976. Les résultats montrent que des rapports élevés coût-avantages sont obtenus dans le cadre des suppositions les plus pessimistes. En outre, on peut également constater que davantage de vaccinations aurait pu donner un rendement bien supérieur. Un modèle épidémiologique Reed-Frost est utilisé afin de découvrir les avantages supplémentaires de la vaccination. Il en résulte un niveau d'immunité du troupeau de 59 pour cent en ce qui concerne les animaux de 6 à 26 mois.

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A BENEFIT-COST ANALYSIS OF MEASLES VACCINATIONS IN YAOUNDE, CAMEROON

Introduction

Benefit-cost analysis is often used in both rich and poor countries when deciding which industrial and infrastructural projects to undertake. This method of project analysis is seldom, though increasingly, used to evaluate the merits of health programs. This paper[1] discusses some of the issues involved in applying the benefit-cost framework to health programs and suggests a method for handling them. The methodology is used to analyze the performance of the measles vaccination campaign carried out in Yaounde, Cameroon in 1971-76 and to show how its results could be used to plan future campaigns. Throughout, the difficulties and weaknesses of the benefit-cost approach are noted.

Methodology

To introduce the methodology used here, the assumptions of previous studies of the benefits to improved health are laid out. Then, the methodology accepted is explained, along with the use of an epidemiological model of measles to link benefits and costs. The studies reviewed are mainly evaluations of the benefits of health improvements, or the costs of illness (which are analytically the same). Differences arise among them over how some of the benefits, particularly indirect benefits, should be evaluated. The method used here to evaluate measles vaccinations tries to resolve these differences and extend the analysis by comparing the benefits of measles avoidance with the costs of giving vaccinations.

Benefit-cost analysis is invoked as a tool of evaluation when the market mechanism fails to allocate resources in a socially optimal way. This failure occurs when benefits or costs arising from an activity escape the private accounting calculations of those affected by the activity. The benefits and costs which escape private accounting are called spillover, external, or indirect effects of the activity.

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[1]This paper is a summary of the methodology and conclusions of the author's doctoral dissertation. See W.M. Makinen, "A Social Benefit-Cost Analysis of Anti-Measles Vaccinations in Yaounde, Cameroon" (Ph.D. dissertation, University of Michigan, 1979).

In the analysis of health-improvement benefits, there is general agreement that the direct benefits to a health-improving activity are the avoided outlays for the detection, cure, and prevention of an illness[2] as well as costs of rehabilitation of its victims. The indirect benefits are classified as productivity effects (loss of physical output avoided) and utility effects (avoided pain or gain in pleasure to illness victims and others).

Productivity benefits are usually measured as the present value of avoided future earnings losses of illness victims. A general formula for calculation of these benefits is:

$$P.V.L. = \sum_{n=a}^{\infty} L_n Y_n p_a^n \left(\frac{1+g}{1+r}\right)^{(n-a)} \tag{1}$$

where P.V.L. is the present value of the earnings loss avoided; L_n is the proportion of earnings loss attributable to the illness in year n; Y_n is average earnings (or value added) of a victim in year n; p_a^n is the probability in the current year (a) of the victim being alive in year n (exclusive of the effects of the illness being evaluated); g is the expected rate of productivity growth; and r is the social rate of discount.

Disagreement arises over how to treat unemployment and the value of women's household services in calculation of average annual earnings[3] and over what rate of discount is appropriate. The positions taken by the studies reviewed on these and other issues are summarized in Table 1.

It is felt by some[4] that the creation of additional labor by health improvements should be evaluated as the expected earnings of that labor,

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[2]The same kind of analysis would apply to accident as well as illness prevention. This paper uses illness as a generic term for both.

[3]B.A. Weisbrod, Economics of Public Health (Philadelphia: University of Pennsylvania Press, 1961) suggested that the present value of an individual's earnings net of consumption be used to measure the productivity loss, but virtually all who have followed use gross earnings.

[4]J.E. Grogan and M.C. Smith, "The Economic Cost of Ulcerative Colitis: A National Estimate for 1968," Inquiry 10 (June 1973): 61-68; Ronald G. Ridker, Economic Costs of Air Pollution (New York: Frederick A. Praeger Publishers, 1970).

TABLE 1

ASSUMPTION OF ILLNESS COST STUDIES

Author	Discount Rate	Employment (Full/ Frictional/Expected Future Rate)	Imputes Value to Housewives' Services (Yes/No)	Growth Rate of Future Earnings	Estimate of Pure Consumption Loss Caused by Illness (Yes/No)
Weisbrod (1961)	10	Full	Yes	--	No
Mushkin (1962)	8	Fric	No	3	No
Fein (1970)	4	Fric	No	--	No
Mushkin & Weisbrod (1964)	na	na	na	na	No
Klarman (1965)	4	Full[a]	Yes	1.75	Yes
Axnick (1969)	4	Full	Yes	1.75	No
Ridker (1970)	5,10	EFR	No	--	No
Grogan & Smith (1973)	6	EFR	Yes	1.75	No
Rice (1966)	6,8	Full	Yes	1.75	No

NOTE: na = not applicable.

(a) Klarman used a proxy for the stigma effect of employment of syphilis victims.

adjusted downward to account for the probability that the labor will be unemployed. However, the prevailing view seems to be that of Mushkin,[5] who says that the failure to employ potentially productive resources should be charged against macroeconomic policy in social accounts and should not result in a diminution of the benefits counted as arising from improved health. Some adjustment of expected earnings is made, though, for frictional unemployment, or that minimum rate below which unemployment can never fall, regardless of the nacroeconomic policies pursued.

In evaluating measles vaccinations in the present study, a variation on this approach to unemployment is used. It is assumed that macroeconomic decision makers set their policies so as to weigh the costs of unemployment against the benefits of other, conflicting macro objectives. Thus, the rate of actual unemployment should reflect some macro calculation of an "optimal" rate. Therefore, expected actual rates of unemployment are used to adjust future earnings gains to reflect conscious macro tradeoffs.

The value of the household services of women is not captured by most measures of earnings. Therefore, it is often omitted[6] from calculations. Most of those who omit the value of household services agree that, in principle, they should be counted, but argue either that to measure them is too difficult or that their value is insignificant, relative to total benefits. This study rejects these claims and approximates the value of household services by the wages of domestic servants,[7] who perform similar services. The value of household services is used three times in the measles-vaccination analysis: as part of the productivity loss avoided by preventing measles deaths; as a part of the care cost of ministering to children ill with measles; and as part of the cost of vaccination, as the value of mothers' time foregone in taking children to vaccination sites.

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[5] Selma Mushkin, "Health as an Investment," Quarterly Journal of Economics 76 (October 1962): 129-157.

[6] It is included by Grogan and Smith (1973); Weisbrod (1961); and Herbert E. Klarman, "Syphilis Control Programs," Measuring Benefits of Government Investment, ed. Robert Dorfman (Washington, D.C.: Brookings Institute, 1965), pp. 367-414. It is excluded by Mushkin (1962); Ridker (1970); and Rashi Fein, Economics of Mental Illness (New York: Basic Books, 1958).

[7] Following the suggestion of Klarman (1965).

The third element of controversy in measuring productivity benefits is the choice of a rate of interest to discount future earnings to their present value. The higher the rate chosen, the smaller the weight assigned to future as compared to present earnings. Many different rates are used (as shown in Table 1). Criteria for selection of a rate of discount include the rate of return earned on capital, the cost of government long-term borrowing, the premium required to induce consumers to postpone consumption, and various schemes to capture the intergenerational responsibility of society. In the end, none of these criteria are totally satisfactory. This study uses a range of discount rates: 5, 10, and 15 percent, to illustrate the significance of the choice to the size of net benefits.

The pure utility loss due to poor health is much discussed in the health-benefit literature, but no conclusion is reached on how to measure it.[8] Utility losses in the form of pain, suffering, and death are identified as affecting not only the illness victim, but also the victim's family, close friends, and even society at large. Because no good means of measurement has been developed, the gains from the avoidance of the pure utility costs of illness are omitted from this study.

The issue of the population growth consequences of death-postponing health programs is little discussed, as most of the studies have been carried out in the United States, where population growth is not regarded as a major problem. This is not the case in many areas of the world, however. Fein[9] showed that many types of health improvements would not have deleterious population consequences, but those postponing deaths, e.g. measles vaccinations, certainly could. The cost of population control policies sufficient to offset any population growth arising from a program would represent an upper limit to the population costs of the project.[10] This technique is used here.

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[8] The exception is Klarman (1965) who approximates the pure disutility of having syphilis by the cost of treatment for psoriasis, which, it is claimed, causes similar disutility without any other consequences.

[9] Rashi Fein, "Health Programs and Economic Development," in The Economics of Health and Medical Care (Ann Arbor: University of Michigan, 1964).

[10] When population control intervention is less costly than the burden of additional population created by a program, the intervention should be undertaken; thus, the population cost of the program would be the intervention cost. If the burden cost were less than the intervention cost, then the intervention should not be undertaken. The intervention cost would always represent an upper limit to the population cost of a project.

Background to Measles in Yaounde

Before laying out the benefit-cost structure, a brief background to the study is in order. Yaounde is the capital and second-largest city (1976 population about 250,000) in Cameroon, Central Africa. Its economy is dominated by the government and service sectors. Per capita income was about 76,000 CFA[11] ($US 304) in 1976. Unemployment is high; it was about 26.5 percent in 1969 [12] and is probably at a similar level now.

Measles is a serious illness in Yaounde. Virtually all children not made immune by vaccination contract measles by age four years.[13] The relatively young age of onset,[14] malnourishment, and other factors make measles in Yaounde a high mortality illness. Although no data are available for Yaounde, its measles case-fatality rate is probably on the order of the 5 to 10 percent found in other urban African sites.[15]

Benefits and Costs of Vaccination

The incidence of measles in Yaounde results in four types of costs: formal medical care costs (hospital stays and clinic visits), household care costs (time foregone in households to give care to measles victims), future productivity losses (the lost future earnings of children who die from measles), and suffering and grief costs (the pure utility losses associated with illness and death). These costs are the benefits to measles avoidance.

The costs of giving vaccinations also fall into four categories: direct fixed costs (mainly administration), direct variable costs (vaccines, personnel, and variable transport and materials), indirect costs (time foregone by parents

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[11] 250 CFA = $US 1.00.

[12] Cameroon Government, Direction de la Statistique et de la Comptabilite Nationale, La Population de Yaounde en 1969 (1970, pp. 22 and 52).

[13] Estimate derived from data in B. Guyer, A.M. McBean, and J. Nakano, "Surveillance of Urban Measles in Yaounde, Cameroon (Central Africa), 1968-1975" (Unpublished document, l'Organization de Coordination pour la lutte Contre les Endemies en Afrique Centrale, 1976).

[14] Average age of onset is less than two years, Guyer, et. al. (1976).

[15] Makinen (1979, pp. 80-84).

bringing children to vaccination sites as well as their transportation costs), and pure utility costs (the disutility of being vaccinated). No cost is charged for the population growth consequences of measles avoidance in the first few calculations, since it is a policy of Cameroon not to interfere with population growth. Later calculations will show the effects of the opposite policy, i.e., a negative value to death postponement.

The benefits to avoiding measles and the costs of giving vaccinations are linked by an epidemiological model which shows how many avoided cases of measles result from each additional immunication produced through vaccination.

Estimation of Benefits

The benefits estimated are the costs avoided by avoiding measles. Each of the four costs of measles indicated above is estimated, with the exception of the pure utility loss.

Formal medical care costs per measles case are estimated from data on the type, cost, and duration of care. Two types of formal care are given to measles victims: hospitalization or severe cases and ambulatory clinic visits for less-serious cases. The hospitalization rate is estimated to be 5 percent of all cases,[16] the average length of hospitalization 7.5 days,[17] and the total cost of a day of hospitalization (including actual cost paid by patients and a government subsidy) 2,000 CFA [18] An adjustment is made to the nominal cost

[16] For a conservative estimate for urban Yaounde, based on the findings of a study of Central Africa as a whole, see C. Gateff and B. Durand, "Rentabilite Economique de la Vaccination Antirougouleuse dans les Cinq Etats d'Afrique Centrale," Afrique Medicale, 14 (1975): 319-323.

[17] Y. Agboton, "La Vaccination Contre la Rougeole en Afrique Tropicale," (Medical thesis, University of Dakar, 1969); M. Rey, I. Diop Mar, and A. Sow, "Rentabilite de deux vaccinations de masse en Afrique," Courrier Centre International de l'Enfance, (1972, pp. 246-50).

[18] Based on estimates made by Gateff and Durand (1975); Agboton (1969); J.R. Mbarga, "Les Aspects Particuliers de l'Economie Medicale en Republique Unie du Cameroun," Medecine d'Afrique Noire, (1974): 904-17; and Cameroon Government, Direction de la Statistique, Bulletin Mensuel de Statistique, 1973-1976.

of hospitalization to reflect the true scarcity of the foreign exchange[19] used by hospitalization; this adjustment brings the real cost per day to 2,062.5 CFA. The average real cost of hospitalization per case is 773 CFA ($US 3.09).

A similar estimate is made for the cost of clinic visits. An average of one clinic visit is made for each less-severe case;[20] the nominal cost of a clinic visit is 900 CFA;[21] and the real cost, adjusted for foreign-exchange use, is 922.5 CFA ($US 3.69). The total formal medical care cost per case is 1,696 CFA ($US 6.78).

Household care costs are based on an expected extra 18 to 34 hours[22] of mothers' time spent caring for children with measles. Estimates of the marginal value of mothers' time are made from census[23] and social survey[24] data on women's workforce activity status by age and estimates of the earnings[25] of women in the various sectors of activity. The wage paid domestic servants, 8,495 CFA per month,[26] is used to approximate the earnings of women in the non-formal sector and those engaged in own-household services. Women engaged in formal sector work were assumed to earn average formal sector

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[19] This adjustment process or "shadow pricing" is necessary when countries hold the exchange rate for their comestic currency artificially high, thus understating the true value of imported items. The World Bank estimates that at the stated exchange rate the CFA is undervalued by 25 percent. Hence all foreign exchange costs and savings have been inflated by 25 percent to reflect true scarcity value

[20] Gateff and Durand (1975).

[21] Gateff and Durand (1975); Agboton (1969); and Cameroon Government, Bulletin Mensuel de la Statistique.

[22] The average duration of measles illness is nine days. The lower time estimate is two hours per day of illness; the higher is ten hours for each of two days, then two hours each for the remaining seven days.

[23] Cameroon Government, La Population de Yaounde en 1969 (Yaounde, 1970).

[24] Cameroon Government, Direction de la Statistique, Enquete Sur le Niveau de Vie a Yaounde 1964-1965 (Paris, 1965).

[25] Earnings or the wage are assumed to represent the marginal value of time, whether lost time is taken from leisure or productive activities.

[26] Cameroon Government, Bulletin Mensuel de la Statistique, 1976.

wages, 24,172 CFA per month. Women in either traditional sector or own-household services represented 68.6 percent of the total, those in the formal sector, 7.7 percent, and those unemployed or not seeking work, 23.7 percent. Average monthly earnings of women of the age of motherhood (15 to 44 years) is calculated as 8,398 CFA. Since mothers are less likely than non-mothers to hold formal sector jobs, this figure calculated for all women is likely an overstatement of mothers' earnings. In the absence of data on the extent of this overstatement, an arbitrary 25 percent reduction in the wage is made. The monthly earnings of Yaounde mothers is thus 6,298 CFA ($US 25.19). The 18 to 34 hours of household care costs of a case of measles is evaluated at 595 to 1,122 CFA ($US 2.38 - 4.49).

The future productivity cost of measles is the present value of future earnings of children killed by measles. To estimate the present value of future earnings the following data are necessary: current earnings, expected growth in productivity, labor force participation rates by age, survival rates, employment rates, and the social rate of discount. These data are plugged into equation (1) to produce the productivity benefit to avoiding a measles death in a given year for a child of a given age.

Census[27] and social survey[28] results are used to find all of the needed data, except productivity growth and the social discount rate. Included in the calculated value of current earnings is an estimate of the value of women's household services based on the wages of domestic servants. The output of persons engaged in either the traditional sector or household services is not expected to grow over time, but formal sector productivity is expected to grow. Productivity in the formal sector grew at 3.7 percent per year over the period 1965-1969[29], but a more reasonable expected future rate might be 2.0 percent. Both rates are used and their results compared below. As noted, selection of a social discount rate is difficult, so a range of values (5, 10, and 15 percent) is used. Current (1976) annual earnings per worker are 523,478 CFA ($US 2,094) in the formal sector and 101,940 CFA ($US 408) in the traditional and

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[27] Cameroon Government, La Population de Yaounde.

[28] Cameroon Government, Enquete Sur le Niveau de Vie.

[29] Cameroon Government, Le Troisieme Plan Cinquennuel de Developpement Economique et Social (Yaounde, 1970).

household sector. The size of the productivity loss per measles case depends on the case-fatality rate which is expected to be between 5 and 10 percent.

Table 2 shows the range of expected total benefits per case of measles avoided given the various assumptions. Clearly, the estimates are highly sensitive to the choice of discount and productivity growth rates as well as the case-fatality rate. The highest estimate is 38 times the lowest.

This discrepancy would not be a problem if there were a single rate of discount chosen for use in an overall planning process and if there were better data (i.e., information as to the true measles case-fatality rate). In order to make appropriate policy judgments based on the results of benefit-cost analysis, it is necessary to use consistent values in the evaluation of all proposed projects. Therefore, some specific interest rate would be used to discount future costs and benefits of all projects, including dams and irrigation schemes as well as health programs. Similarly an appropriate rate of productivity growth would be used throughout any plan.

This study will use the lowest estimated benefit per avoided measles case, 11,617 CFA ($US 46.47), in all future calculations. Thus, the results should indicate the minimum benefits attainable through vaccination.

Cost of Vaccination

Estimation of the costs of vaccination[30] is easier than estimating benefits. Direct fixed and variable costs of vaccination are estimated from a past vaccination campaign.[31] Foreign exchange spending is adjusted for its undervaluation as before. A similar but downward adjustment is made for the cost of unskilled labor used in giving vaccinations, as it must be paid a minimum wage which overstates its scarcity value (see the unemployment rate). The results of these calculations and adjustments; real annual fixed costs of a vaccination campaign are 697,400 CFA ($US 2,790) and the real variable direct cost per vaccination given is 60.1 CFA ($US 0.24).

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[30] Again, the pure utility costs of vaccination are ignored because of measurement difficulties.

[31] B. Guyer and S. Stangana, "A Program of Multiple Antigen Childhood Immunization in Yaounde, Cameroon," (Unpublished manuscript, Yaounde, 1977).

TABLE 2

BENEFIT PER MEASLES CASE AVOIDED, YAOUNDE, 1976

Medical Care Cost/Case[a]	Mother's Time Cost/Case[b]	Case-Fatality Rate[c]	Discount Rate[d]	Productivity Growth Rate[e]	Total Cost/Case (In CFA)
X	L	L	H	L	11 617
X	L	L	H	H	16 473
X	H	L	H	L	12 144
X	H	L	H	H	17 000
X	L	H	H	L	20 999
X	L	H	H	H	30 701
X	H	H	H	L	21 516
X	H	H	H	H	31 228
X	L	L	I	L	32 903
X	L	L	I	H	51 218
X	H	L	I	L	33 430
X	H	L	I	H	51 745
X	L	H	I	L	63 561
X	L	H	I	H	100 190
X	H	H	I	L	64 098
X	H	H	I	H	100 717
X	L	L	L	L	133 295
X	L	L	L	H	224 238
X	H	L	L	L	133 812
X	H	L	L	H	224 765
X	L	H	L	L	264 345
X	L	H	L	H	446 231
X	H	H	L	L	264 872
X	H	H	L	H	446 758

NOTE: The following symbols are used:
X = value used
L = low value used
I = intermediate value used
H = high value used

[a]Medical care costs were estimated to average 1,696 CFA per case.

[b]Two values were estimated for mother's time loss per case: H=1,122 CFA, L=595 CFA.

[c]Two case fatality rates are used: H=.10, L=.05.

[d]Three discount rates are used: H=.15, I=.10, L=.05.

[e]Two productivity growth rates are used: H=.037, L=.020.

The indirect costs of vaccination are the costs of transporting children to vaccination sites and the time foregone by mothers in accompanying them. Transport costs are one-half round-trip bus fare (25CFA), since only some vaccinees travel by bus. The value of mothers' time foregone is estimated as before, and the amount of time spent per child comes from a study of "wait time."[32] Wait time is approximately two hours, making the time-foregone cost 91 CFA and the total direct and indirect variable cost of vaccination 151.1 CFA ($US 0.604).

The costs of vaccination and the benefits from avoiding measles have been presented. However, there is a link that must be made between giving vaccinations and preventing measles. Since nearly all unvaccinated children in Yaounde get measles, each effective vaccination[33] prevents at least one case of measles. In addition, each child made immune through vaccination reduces the number of infectious children in the population, hence reduces the chances of susceptible children contracting the illness. This external benefit to vaccinations may be captured by an appropriate specified epidemiological model.

A modified Reed-Frost model of measles spread with the following case-generating equation is used:

$$C_t = S_t \cdot [1 - \frac{a_t}{P_t})^{C_{t-1}}] \qquad (2)$$

where C_t is the number of measles cases occurring in month t; S_t is the number of susceptibles; a_t is the average number of effective contacts between individuals; and P_t is the total population size. Effective vaccination impact on monthly case incidence is modelled by subtracting susceptibiles.

Base-line population data from census records, estimates of susceptibility from serological surveys, [34] records of reported cases, and estimates of vaccination effectiveness[35] are used to find the parameters of the model. An annual

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[32] Guyer and Atangana (1977).

[33] An effective vaccination is one which confers immunity to the vaccinee.

[34] B. Guyer, "Results of Sero-epidemiological Evaluation of a Measles-Smallpox Vaccination Program in Yaounde--June 1975," unpublished OCEAC report (Yaounde, 1976); P. Djogdom, J. Nakano, and D.L. Heymann, "The Expanded Program in Immunization--Yaounde, Evaluation of the First Two Years," unpublished OCEAC report, (Yaounde, 1978).

[35] Reported cases and vaccination effectiveness data come from unpublished statistics gathered by B. Guyer and D.L. Heymann at OCEAC, Yaounde.

pattern of effective contacts was found, with a peak in December and a trough in September.

Benefit-Cost Estimates

This epidemiological mode is used to simulate the incidence of measles that would have occurred without vaccinations over the years 1971-1976 (Table 3). Without-vaccination incidence is compared with actual incidence; the difference in cases multiplied by the benefit per case avoided is the benefit attributable to the vaccinations given. The cost of the 68,809 vaccinations actually given[36] is estimated, then compared with the benefits, producing 322 million CFA ($US 1.2 million) in net benefits and a 23.3:1 benefit-cost ratio. Clearly, measles vaccinations are socially profitable using our estimates of benifits and cost.

This analysis of the actual 1971-76 vaccinations indicates that had more vaccinations been give, even greater net benefits could have been attained. The only limit on producing benifits over costs by vaccinating would seem to be that there be cases to be prevented.

In a given population there may be a level of immunity sufficient to choke off the spread of an infectious disease for lack of susceptibles. This is called the level of "herd immunity." Once this level of immunity was reached there would be no more case avoidance possible by additional vaccination. Hence, the epidemiological mode was asked to find the herd immunity level for Yaounde. At a sustained level of immunity of 59 percent in the population aged 6-36 months, the incidence of measles would eventually fall to zero. At higher levels, incidence would drop more rapidly, at lower levels measles would continue to be endemic.

Calculation of net benefits arising from vaccinations given to reach and exceed the herd immunity level, show that benefits in excess of costs may be earned for additional vaccinations until virtually every child is effectively vaccinated.[37] These calculations are made using two critical assumptions, viz. vaccination effectiveness[38] could be maintained at 48.5 percent as it had

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[36]Only 33,344 vaccinations were considered effectively given, or 48.5 percent.

[37]The highest benefit-cost ratio is reached at vaccinations producing 60 percent immunity among the 6-36 months age group.

[38]Vaccination effectiveness is the percent of inoculations given which give immunity to measles to the vaccinee. As will be seen below there are many reasons vaccination effectiveness may be less than 100 percent.

TABLE 3

BENEFITS AND COSTS OF THE 1971-1976
YAOUNDE MEASLES VACCINATION PROGRAM

Cases Without Vaccination	58 093
Cases With Vaccination	28 400
Difference	29 693
Benefit (thousands of CFA)	337 341
Vaccinations Given	68 809
Cost (thousands of CFA)	14 506
Net Benefit (thousands of CFA)	322 835
Benefit/Cost	23.2:1

during the actual 1971-76 program and the cost of giving additional vaccinations would remain constant.

There are reasons to believe that effectiveness might decline and the cost might rise as more vaccinations are given in a given time period. Effectiveness might fall as the probability of mistakenly vaccinating someone already immune rises and as additional, less-experienced vaccination workers are hired. In addition, to protect all susceptibles it become necessary to vaccinate children closer to the age at which they are protected by maternal antibodies;[39] vaccination of those who are still protected by the antibodies renders the vaccination useless. The cost of giving vaccinations may rise as the difficulty of finding susceptibles increases. If the quality of vaccination workers is to be maintained, it may be necessary to increase training, pay, or both.

Given rising costs or falling effectiveness of vaccination and the possibility of herd immunity, the rising marginal cost may meet the declining marginal benefit of vaccination short of vaccinating to the level of complete immunity.[40] No data are available on rising vaccination costs and only point data are known for vaccination effectiveness. To illustrate how declining effectiveness could be used to find the optimal level of vaccination, three hypotheses as to the rate of effectiveness decline are constructed from the point data.[41] They are used to estimate economically optimal (i.e. net benefit maximizing) levels of vaccination. Table 4 compares the benefit-cost analysis of the actual annual average vaccination program carried out in 1971-76[42] with an optimal level program, calculated assuming an intermediate rate of decline in vaccination effectiveness. The 82 percent increase in the number of vaccinations given produces a 53 percent decline in measles cases, but any additional vaccinations would cost more than the additional benefit they would produce and net benefit would decline from 83 millin CFA shown.

Sensitivity Tests

The results presented show that measles vaccinations were socially profitable

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[39] Usually six to nine months.

[40] Where rising marginal costs are equal to declining marginal benefits, net benefits are maximized.

[41] See Makinen (1979, pp. 151-157) for details.

[42] This benefit-cost calculation for the 1971-1976 programs differs slightly from that presented in Table 3 because it takes into account reduced measles incidence beyond 1976 resulting from lowering the number of infectious children during the program.

TABLE 4

COMPARISON OF OPTIMAL AND ACTUAL ANNUAL VACCINATION LEVELS

	Actual	Optimal
Annual Vaccinations	11 468	20 858
Percent Effective	48.5	38.1
Marginal Effectiveness[a]	.134	.014
Effective Vaccinations	5 562	7 954
Avoided Cases/Effective Vaccinations	.95	.94
Marginal Cases Avoided[b]	.127	.013
Avoided Cases	5 284	7 477
Cost (millions of CFA)	2.43	3.85
Benefit (millions of CFA)	61.38	86.86
Benefit/Cost	25.3	22.6
Net Benefit (millions of CFA)	58.95	83.01

[a]Probability of effectively conferring immunity from measles with the last vaccination given.

[b]Expected number of measles cases avoided by the last vaccination given.

for Yaounde in 1971-76 and that they could have been even more profitable if an optimal level of vaccination had been used. Thes results are produced using the lowest of the measles-avoidance benifit measures shown in Table 2; using any of the other estimates of benefits would produce even larger social profits. However, there are some assumptions embodied in even the smallest benefit estimate that might be questioned. Therefore, analysis of the benefits and costs of an optimal vaccination scheme for 1976 assuming a rapid rate of decline in effectiveness is done with even more restrictive assumptions about benefits. It is assumed that no gain in future productivity will result from the avoidance of measles deaths,[43] that the marginal value of household time is zero, and that there are negative population consequences of saving lives which cause the expenditure of 12,500 CFA for birth control as the result of each life saved. These assumptions severely reduce the benefits and raise the costs of vaccination (Table 5), but leave intact the conclusion that vaccinations produce social net benefits.

CONCLUSION

Benefit-cost analysis may be applied to health programs like measles vaccinations. There are some conceptual problems, to which this paper proposed some solutions. Some of the problems can be overcome by simply making health programs part of the overall planning process, others by gathering better information. Measles vaccinations in Yaounde appear to be an overwhelmingly favorable project, no matter what restrictions are placed on benefits. This result suggests that there may be a broad underallocation of funds to health projects, so that wider application of benefit-cost analysis to health programs may result in bigger health budgets, hence better health and a net social gain.

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[43] This could result if the marginal productivity of labor were zero.

TABLE 5

BENEFITS TO MEASLES AVOIDANCE

(Excluding Household Costs and Productivity Losses, Including Costs of Birth Avoidance)

Benefit/Avoided Case (CFA)	1 650
Annual Vaccinations Given	11 560
Cost of Vaccination (millions of CFA)	2.36
Avoided Cases	5 017
Avoided Deaths	251
Cost of Birth Avoidance (millions of CFA)	3.14
Total Cost (millions of CFA)	5.50
Benefit (millions of CFA)	8.28
Benefit/Cost	1.5
Net Benefit (millions of CFA)	2.78

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