Cost-effectiveness of routine and campaign vaccination strategies in Ecuador

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A national household coverage survey of 3697 Ecuadorean children, carried out in July 1986, provided an opportunity for a cost-effectiveness analysis of (1) routine vaccination services based in fixed facilities and (2) mass immunization campaigns. A major purpose of the campaigns was to complement the routine services and to accelerate immunization activities. Based on the coverage survey, the Program for Reduction of Maternal and Childhood Illness (PREMI) and earlier campaigns increased the proportion of children under 5 years who were fully vaccinated from 43% to 64%. In one year, the PREMI campaign was responsible for fully vaccinating 11% of children under one year, 21% of 1–2-year-old children, and 13% of all children under 5 years. The campaign also helped ensure that vaccinations were completed when children were still very young and at greatest risk.

The average cost per vaccination dose (in 1985 US$ prices) was approximately $0.29 for fixed facilities and $0.83 for the PREMI campaign. Total national costs were $675 000 and $1 665 000 for routine and campaign services respectively. The cost per fully vaccinated child (FVC) was $4.39 for routine vaccination services and $8.60 for the campaign. The cost per death avered was about $1900 for routine vaccination services, $4200 for the PREMI campaign, and $3200 for the combined programme. Because of Ecuador's lower mortality rates, the costs per death averted in Ecuador from both vaccination strategies are not as low as those from studies of vaccinations in Africa. The campaigns, though less cost-effective than routine services, significantly improved the vaccination coverage of younger children who had been missed by the routine services. The costs per FVC of both the campaign and the routine services compare favourably with such programmes in other countries.

Introduction

The first major national immunization campaign in Ecuador, launched in October 1985, was coordinated and directed by the PREMI project (Programma de Reduccíon de Enfermedad Materno y Infantil), a child survival programme focusing on immunization, oral rehydration therapy, and growth monitoring. The campaign was actively promoted by the National Institute for Children and the Family (INNFA), and supported by the U.S. Agency for International Development (USAID), UNICEF, and the Pan American Health Organization (PAHO). The campaign, which mobilized health workers, as well as the national army and the Ministry of Education, used the mass media, including television and radio, to emphasize the importance and timing of vaccinations and other health activities. During the first year (October 1985 to June 1986), three rounds of the PREMI campaign were held, each one initially lasting three days. In the next year three more rounds were held, and in 1988 the country switched to two rounds per year synchronized with the campaigns of other Andean nations.

Campaigns are a controversial approach to vaccinations. Proponents contend that they successfully mobilize the political, human, and financial resources, strengthen the country's interest and capacity to deliver vaccinations, and substantially boost coverage. Critics counter that the gains may be short-lived and the campaigns may divert resources and trust away from routine health programmes.

Directed by PREMI, the immunizations (BCG, polio, tetanus, diphtheria, pertussis, and measles vaccines to children less than five years of age, and tetanus toxoid for pregnant women) were provided in

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a variety of health facilities (hospitals, health centres, subcentres and health posts) and other locations such as schools. The third and later rounds of the campaign also included other child survival activities, especially the promotion of growth monitoring and use of oral rehydration therapy (ORT). The PREMI campaign was intended to complement rather than replace the routine immunization services which continued to be performed at most Ministry of Public Health (MOPH) facilities. The MOPH had used limited campaigns (here described as pre-PREMI) from 1981 to 1985 to strengthen the routine services. Each lasted only one day, lacked coordinated publicity, and involved only health institutions.

Cost-effectiveness studies of routine and campaign strategies can help policy-makers from village to national levels to evaluate both approaches (*14*). Many studies report the costs (*9*) or cost-effectiveness of an overall vaccination programme (*1, 6, 19, 20, 23*). Only a few studies, however, have compared the cost-effectiveness of alternative delivery strategies within a single country (*2, 4, 7*).[a] The popularity of the campaign approach makes studies of its cost-effectiveness critical. In the Americas, Brazil, Colombia, El Salvador, Jamaica, and other countries have recently held vaccination campaigns. In other regions of the world, Burkina Faso, Cameroon, Mauritania, Nigeria, Senegal, and Turkey are countries pursuing the campaign strategy.

In the present study, the value of conducting a campaign to supplement routine vaccinations was examined in order to determine (1) the cost, level of coverage, and number of deaths averted by the routine programme alone, (2) increases in cost, coverage, and deaths averted from the campaign, (3) the cost-effectiveness of the routine vaccination programme, and (4) the incremental cost-effectiveness of the campaign. A project report describes the methods, data, results, and sensitivity analyses in detail.[b]

Costs of vaccinations

Routine services (fixed sites)

Methods. The total and average costs of routine immunizations were derived in part from a 1986 study of the costs of primary health services in health subcentres and similar facilities of the MOPH, the rural social security programme, and certain non-profit private organizations in Ecuador (*8*). National costs of routine immunizations were based on site visits to a representative, but non-random, sample of seven public (MOPH) subcentres, eight health posts, seven hospitals, and higher level offices (national and provincial or regional) of the organizations involved. Almost all sites were located in Ecuador's two principal regions—the coast and the Andes. All costs for both strategies are reported in constant 1985 dollars using the mid-1985 (June) conversion rate of 115.52 sucres per US$ 1. Annex A explains the methods.

Cost results and interpretation. The average cost per dose under the routine programme was $0.29 (Table 1); the cost of the extrapolated national programme for routine immunizations at public facilities was approximately $675 000. Within some types of facilities, the unit cost varied substantially. For example, the cost per dose ranged from $0.16 to $1.37 for hospitals. These variations suggest that operations research would be useful to determine the reasons for the differences and how the practices from efficient hospitals may be propagated. A series of sensitivity analyses (summarized in Annex A) indicated that none of the crucial methodological features of the study distorted the results.

PREMI campaign

Methods. For comparability with routine services, the authors chose six provinces for estimating campaign costs from the two major regions and, to a limited extent, the third: Guayas, Los Rios, and Esmeraldas on the coast; Pichincha and Chimborazo in the Andes; and Napo in the east. Standard questionnaires were used at all facilities. On advice from the Ministry of Public Health, the authors selected a representative (though non-random) sample of 30 health facilities in these six provinces. Cost information from these facilities was collected concurrently during the campaign round in June 1986, and the results extrapolated to the total cost of the year's three rounds. Campaign costs included not only activities during each three-day "round", but also the preparatory measures and publicity, visits to households by supervisors, and visits to health facilities immediately after each round. For further details, see Annex B.

Cost results and interpretation. The average cost in the campaign ranged from $0.75 in health centres to $1.06 per dose in health posts (Table 1). The weighted average cost per dose, $0.83, provides a reasonable estimate of the mean cost per dose for PREMI vaccinations. The estimated total annual cost of

[a] **Qualls, N.L.** *Costing methods for preventive health measures in developing countries.* Thesis for M.S. in Public Health. Chapel Hill, University of North Carolina, 1986.

[b] **Shepard, D.S. et al.** *The cost-effectiveness of immunization strategies in Ecuador.* Cambridge, MA, Harvard Institute for International Development, 1987 (unpublished paper).

Table 1: **Cost per dose by strategy and type of facility**

Type of facility	No. of facilities		Mean number of doses[a]	Average cost per dose[b]
	In country	In sample		
Routine vaccinations[c]				
Hospitals	114	7	40 808	\$0.24 (±0.15)[d]
Health centres	54[e]	0	21 454	\$0.33
Subcentres	817	7	2100	\$0.41 (±0.06)
Health posts	232	8	952	\$0.29 (±0.06)
Total[f]	1217	22	6366	\$0.29 (±0.10)
PREMI campaign[g]				
Hospitals	114	9	1320	\$0.94 (±0.07)
Health centres	54	4	2653	\$0.75 (±0.08)
Subcentres	817	8	494	\$0.80 (±0.16)
Health posts	232	9	186	\$1.06 (±0.07)
Total	1217	30	609	\$0.83 (±0.09)

[a] Per sampled facility from records of sampled facilities.
[b] In dollars, 1985 prices. Routine vaccinations are based on data for the calendar year 1985. Free market exchange rate was 115.52 sucres = US\$ 1.00.
[c] In fixed facilities.
[d] Figure in parentheses are standard errors.
[e] Health centres were not included in the sample for routine vaccinations. Mean number of doses and average cost were approximated by interpolation between hospital and subcentre average cost figures.
[f] Mean numbers of doses in total lines and all averages and standard errors of cost per dose are weighted averages (see text).
[g] Campaign in June 1986.

the three-round PREMI campaign in Ecuador was \$1 665 000. Cost profiles by type of input showed that transportation costs accounted for the largest overall share of costs (29%), followed by personnel costs (23%), promotion costs (19%), and vaccines and vaccination supplies and cards (15%). Here, too, sensitivity analyses indicated robust results (see Annex B).

Comparative costs of routine and campaign strategies

The type of unit cost estimated in this study, i.e., the average cost per dose, differed between the two strategies by almost a factor of three (\$0.29 for routine fixed site immunizations and \$0.83 for PREMI). Both these amounts may be underestimates of the complete resources used since both strategies excluded general administrative costs at the national level. Although the samples of facilities studied were not random, they were representative of selected provinces in the two major regions of Ecuador. Since no marked differences in average costs were found among facilities or provinces, the national estimates of costs, both total and average, should not be significantly biased.

Effectiveness

Methods

Levels of vaccination coverage were assessed in a July 1986 national household cluster survey, which examined knowledge, attitudes, and practices related to the use of immunizations, ORT, and growth monitoring. Overall, 2702 households were interviewed, covering a sample of 3697 children: 51.3% in urban areas, and 48.7% in rural areas. Most informants were mothers (94%) and each interview lasted about 30 minutes. Doses were credited to the routine or campaign strategy based on the month in which they were administered.

The number of fully vaccinated children (FVC) is one of the most common measures of the effectiveness of the immunization programme. This measure is a keystone of WHO's EPI costing guidelines[c] and many costing studies have applied the concept (*4, 6*). Assessing the number of FVCs for each strategy is difficult, however, because they are the "joint

[c] *Expanded Programme on Immunization: costing guidelines.* Unpublished WHO document, EPI/GEN/79/5, 1979.

product" of routine services and campaign services. FVCs were allocated in each age group between routine and campaign approaches based on the proportions of final vaccine doses for each disease administered to that age group. For example, the survey found that 63% of one-year-old children were FVCs. The survey also established that one third of the one-year-olds' final doses were received during the PREMI campaign. Therefore, 21% (one third of 63%) of one-year-olds were considered fully vaccinated due to PREMI. Annex C describes the methods further.

Health impacts were measured as the numbers of cases and death "equivalents" averted due to immunization. Death and permanent paralysis were considered as death equivalents. Impacts were derived for routine services alone, the increment from the PREMI campaign, and the combination of routine and campaign strategies. One year of operation of each strategy was considered with results based on the findings of 1985–86. The PREMI campaign was considered part of an ongoing, multi-year series of campaigns that complements the ongoing routine vaccination programme. This perspective implies that the costs of equipment, publicity, and other inputs shared with the routine programme were allocated between strategies according to the share of use (in terms of time or doses) by each strategy. Studies from the beginning of vaccination programmes have projected the numbers of deaths averted as a result of introducing vaccinations to a previously unserved population (*20*). In Annex D, the authors have developed and applied a new method for estimating the lives saved from *improving* the coverage to a partially served population.

Results and interpretation

Figures 1–3 show the vaccination coverage for each vaccine type by attained age (completed years) for routine services and the increments added by campaigns (both PREMI and pre-PREMI phases). BCG coverage for children under 1 was 62% through routine services alone and 94% overall (Fig. 1). The increment (32%) came from the campaign. For all children under 5 years, BCG coverage from routine services was 75%; for both strategies it was 96%, implying an increment of 21 percentage points. As most deliveries occur in health facilities in Ecuador, the target group for BCG (newborns) is easily reached. To protect newborns against neonatal tetanus, their mothers must be vaccinated; only 22% of pregnant women were vaccinated.

Ecuador's immunization programme seeks to fully vaccinate children by their first birthday. The

Fig. 1. **BCG coverage rates.**

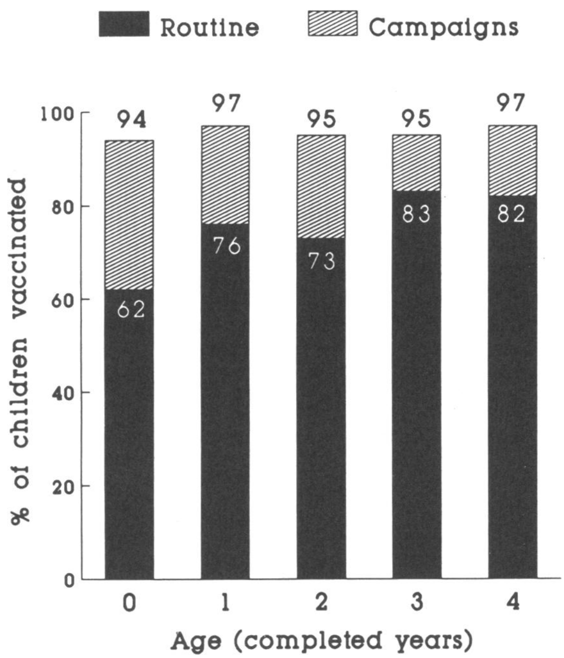


Fig. 2. **DPT coverage rates.**

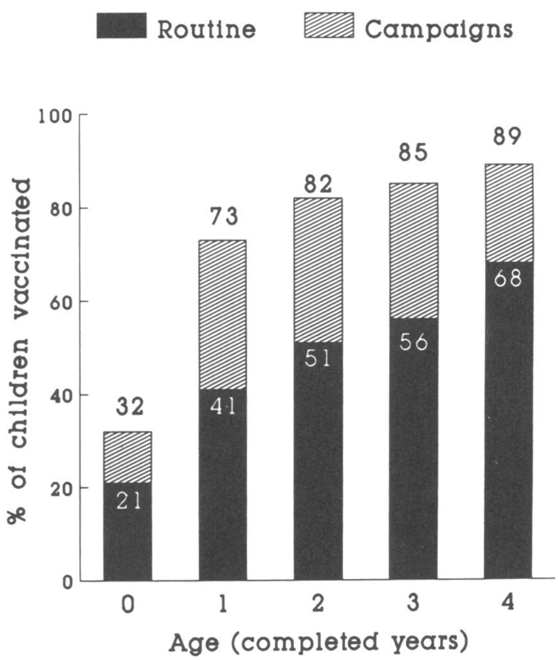


Fig. 3. **Measles coverage rates.**

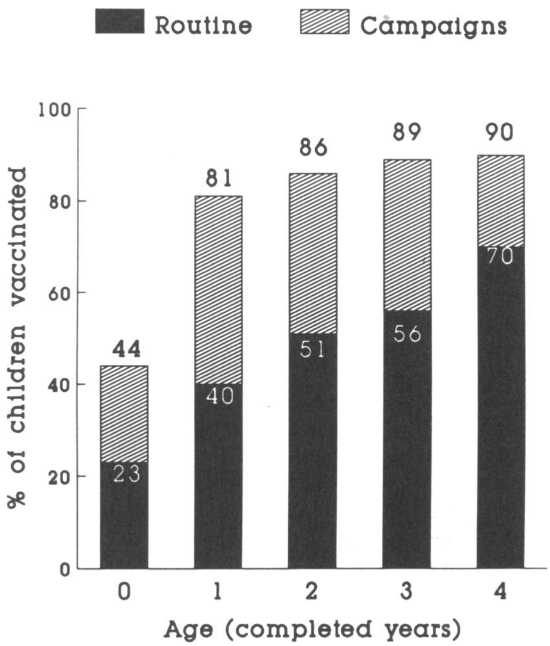
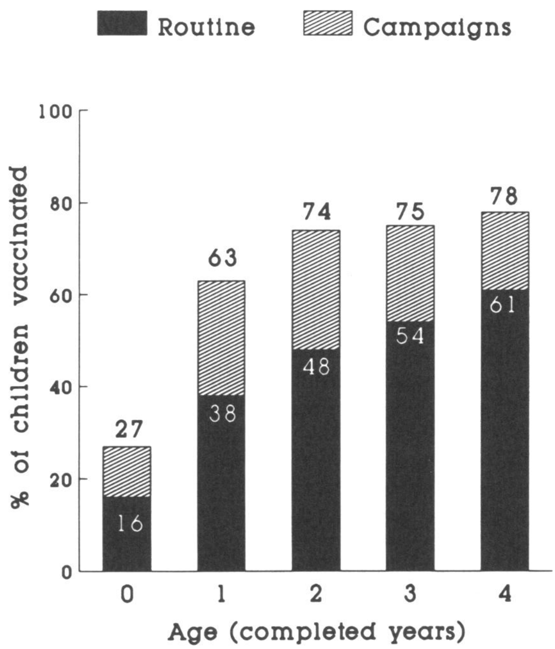


Fig. 4. **Fully vaccinated coverage rates.**



estimated coverage for DPT for children under age 1 (32% by both strategies combined) apparently falls far short of this goal (Fig. 2). As the estimated coverage in the "age 0" category is actually based on the coverage of children age 9–11 months, it underestimates the proportion of children vaccinated by age 1. DPT coverage for children of age 1 (i.e., 12 to 23 months of age) is 73%. Thus, childhood vaccinations were often not missed, but were performed late.

The accuracy of coverage surveys deserves scrutiny. Interpolating between the average ages in both age categories gives coverage of 40% by age 1. The result agrees with the corresponding 1986 coverage reported by PAHO (43%) obtained by dividing the national number of third DPT doses administered to children under 1 (according to the Ministry's data) by the number of children in that age group.[d] Poliovaccine is generally administered concurrently with DPT, so its coverage is almost identical to that of DPT in Fig. 2. Measles coverage shows a similar improvement between age "0" (44% coverage) and age 1 (81% coverage; see Fig. 3). Measles coverage is higher than DPT coverage because measles requires only one dose, compared with three for DPT. The interpolated coverage for "by age 1" of 51% is close to the PAHO rate of 49%.[d] Thus, independent data support the validity of the coverage survey.

The percentage of fully vaccinated children of age "0" by routine services was only 16% (Fig. 4). For all ages, routine services achieved 43% FVC coverage; campaigns added 21% to raise the combined FVC coverage to 64%. Of the increment from campaigns, 8 percentage points were achieved by the pre-PREMI phase, and the remaining 13 percentage points were obtained by PREMI. The PREMI campaign was most effective at improving coverage rates in younger children aged 0–2 years. During the year 1985–86, vaccinations provided through routine services potentially averted the death (or permanent paralysis) of 347 children under 5 years. The PREMI campaign averted the death (or equivalent) of an additional 394 children. The combined programme averted 741 deaths and 156 400 cases.

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[d] **Pan American Health Organization.** *Ecuador EPI general purpose mortality retrieval* (Unpublished tables). Washington, DC, 18 February and 11 March, 1988.

Cost-effectiveness analyses

Cost per fully-vaccinated child

Cost-effectiveness analyses of vaccinations are expressed as the cost per fully vaccinated child[e] or the cost of a specified impact on health. The cost per fully vaccinated child is the national cost of vaccinations in a year divided by the number of FVC. Pre-PREMI campaigns were excluded from the cost-effectiveness analysis because strategy changes and limited data constrained the available services. The results in Table 2 show a clear cost-effectiveness advantage for routine immunizations. The cost per FVC is $4.39 for the routine programme, $8.60 for the PREMI campaign, and $6.74 for both strategies combined.

Cost-effectiveness comparisons between campaign and routine vaccinations are available for a few other countries. Fully immunizing a child through a campaign was generally more expensive than through routine services.[f] In Colombia, the cost per dose through a three-day campaign was $3.60 (in 1984 prices) compared with $2.60 for routine services (*5*). The corresponding costs per FVC were $60 and $27, respectively. In Mauritania in 1985, the cost per FVC was $6.83 for routine services versus $8.97 for a campaign (*23*). In Cameroon, the cost per FVC was $2.19 through routine services and $18.93 through a campaign (*3*). A final analysis of the 1982 Brazilian campaign showed a similar pattern (7); a preliminary study of this campaign had shown it to be more cost-effective (*4*), but methodological limitations may have biased those findings (*10*).

Comparing the unit costs of Ecuador's 1985–86 campaign with similar data from other countries shows that in Ecuador the costs are at the low end of the range from studies elsewhere. The cost per dose in Ecuador's campaign ($0.83) is below that obtained in El Salvador's national campaign ($1.22) conducted during a temporary truce in the country's civil war.[g] The cost per FVC in Ecuador's campaign ($8.60) was similar to that in the Mauritanian campaign ($8.97) noted above, and below the costs in Cameroon ($18.93) or in Nigeria ($10.84) (*3, 23*).

For routine services, Ecuador's cost per FVC ($4.39) is also below that in fixed sites in Mauritania ($6.83) (*23*), Côte d'Ivoire ($16) (*20*), or the Gambia ($14) (*18*). It is similar to the results of earlier studies summarized by several writers (*2, 6, 9, 11, 17*).

Costs in relation to health impacts

As shown in Fig. 5, the national cost per death or equivalent averted is $1900 for routine services, $4200 for the PREMI campaign, and $3200 for the combination of both strategies. The slope in each diagonal line is proportional to the cost-effectiveness of the strategy or combination that it represens. The

[e] **Parker, D.** *Increasing the usefulness of cost-effectiveness analysis in immunization programme management.* Fifth International Congress of World Federation of Public Health Associations, New York, UNICEF, 1987 (unpublished paper).

[f] **Kessler, S. & Blair, P.** *Review of accelerated immunizations.* Unpublished paper for Task Force on Child Survival. Washington, DC, American Public Health Association, 1987.

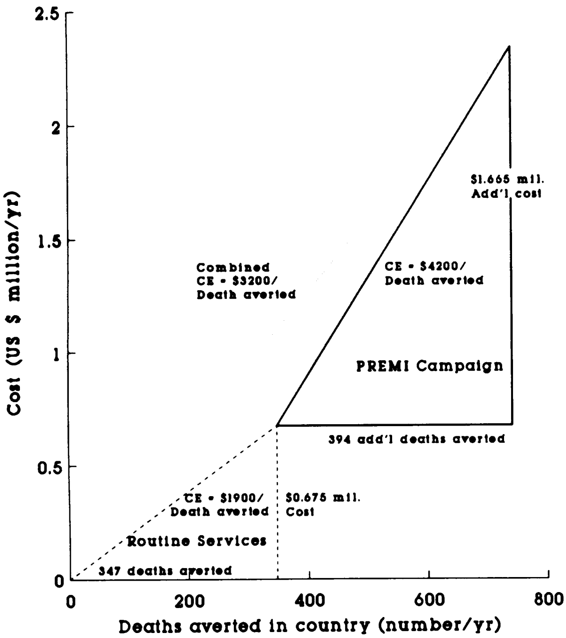
[g] **El Salvador, Ministry of Public Health and Social Welfare.** [*Cost evaluation: national vaccination days.*] San Salvador, 1985 (unpublished, in Spanish).

Table 2: **Costs and cost-effectiveness of vaccination strategies in Ecuador in children under 5 years (July 1985 to June 1986)**

Indicator	Strategy		
	Routine services	PREMI campaign	Both combined
No. of doses	2 300 000	2 000 000	4 300 000
Cost per dose[a]	$0.29	$0.83	$0.55
National cost	$675 000	$1 665 000	$2 340 000
No. of FVC[b]	154 000	194 000	347 000
Cost per FVC	$4.39	$8.60	$6.74
Death equivalents averted	347	394	741
Cost per death equivalent averted	$1900	$4200	$3200
Cases averted	61 100	95 300	156 400
Cost per case averted	$11.05	$17.47	$14.96

[a] 1985 prices in US$.
[b] FVC = fully vaccinated children.

Fig. 5. **Cost-effectiveness of routine and PREMI strategies.**



costs per case averted are $11.05 for routine services, $17.47 for the PREMI campaign, and $14.96 for the combination. The routine strategy was more cost-effective than the campaign for 1985–86, primarily due to its lower cost per dose. These results confirm that Ecuador would not want to consider designing a campaign ro *replace* routine vaccinations. As a complement to routine services the campaign is more expensive, but reaches less accessible children.

Only a few other cost-effectiveness studies have examined the cases and deaths prevented by immunization (*9*). Two African studies are worth noting. In the Gambia the cost of routine services per case prevented from all EPI diseases except tuberculosis was $8.43 and the cost per death averted was $158 (in 1980–81 prices) (*19*). For Côte d'Ivoire, the cost of routine services per *measles* death averted was $850 in 1985 prices, which yields about $570 per overall death averted (*20*).

These results indicate that more money must be invested in Ecuador to avert the death of a child from disease-related illness than had been required in these other countries. The main reason is that the mortality rates from EPI diseases in unvaccinated children are not as severe in Ecuador as in these two African nations. For example, measles mortality rates imply that an unvaccinated child faces a cumulative risk of measles death before age 5 of only 0.24% compared with a 12-fold higher risk of 3% in the Côte d'Ivoire (as of 1980) (*20*).

Ecuador's 1987 mortality rate of 89 for children under 5 years of age per 1000 live births is better than that in 65 other developing countries (*22*). In general, if a country's under-five mortality rate is low, then steps to achieve further improvements are relatively difficult, costly and not highly cost-effective. Overall, Ecuador's cost per vaccine-related death averted of $3200 from the combined strategies lies at the centre of the range of $210 to $5300 for a compilation of nine primary health care strategies (*20*).

Discussion and conclusions

A major goal of the PREMI vaccination campaign was to augment inadequate levels of vaccination coverage. To achieve that goal, PREMI aimed to vaccinate children not being covered by the existing routine programme. Three indicators suggest it succeeded, at least in the short run.

First, this paper has reported on the distribution of numbers of doses by presumed strategy from the 1986 coverage survey. About a third of all doses received by children under-five were provided through the PREMI campaign. The authors assumed that doses delivered during the campaign would not otherwise have been provided by routine services. Using data from the 1986 coverage survey, the authors calculated that one year of PREMI vaccination campaigns increased the coverage achieved through routine services by a half (from 43% to 64% of children under 5 years fully vaccinated).

Second, other researchers (E. Contreras Budge & R. Hornik), using a precise before-and-after comparison to determine the increase in coverage from a single round of the PREMI vaccination campaign, calculated the vaccination coverage before and after 26 January 1986, the date of the second round of the PREMI campaign (R. Hornik, personal communication, 1989). Their calculations used a subsequent national coverage survey conducted in April 1987. The analysis defined the "before" period as the year prior to 26 January 1986, and the after" period as the thirteen months following that date. Vaccination coverage of one and two year-olds was based on the percentage of surveyed children with all required vaccinations (not taking BCG into account) documented by the date of their first or second birthday, respectively. The 1987 survey showed that the coverage of one-year-olds rose from 15% to 37% and that of two-year-olds increased from 42% to 52% from the pre- to the post-campaign periods. Thus, these before-and-after comparisons used a later survey and a different method for estimating the campaign's contribution. The findings were entirely consistent, however, with those from the approach described in this paper.

Third, in unpublished data Contreras Budge and Hornik also analysed the coverage for one-year-olds in the 1987 survey according to an index of socio-economic status (SES). The index was based on education, water supply to the household, presence of a radio in the household, and other factors. Coverage rose from pre- to post-campaign periods in all three SES groups: in the low SES group, from 6% to 27%; in the medium group, from 8% to 31%; and in the high group, from 22% to 41%. Changes along a percentage scale such as these are often transformed to a logistic scale, as the latter adjusts for threshold and ceiling effects of 0% and 100%, respectively. According to both the logistic and the original linear scales, the rise was greatest in the low and medium SES groups. These results indicate not only that the second round of the PREMI vaccination campaign was associated with a substantial increase in coverage, but also that children in the SES groups which were reached least by the existing services benefited most.

Health officials are also concerned about the long-term effects of vaccination campaigns, some of them arguing that they may undermine the routine services in the long run. To try to analyse this concern, the authors examined the national vaccination coverage in Ecuador for the years before and after the PREMI vaccination campaign. PAHO's computation of Ecuador's vaccination coverage for children under one year of age, based on data from Ecuador's Ministry of Health,[h] takes the number of children receiving a specified dose (e.g., third dose of DPT) and divides this by the number of children under the age of 1 year in the country. These data show that the coverage of the third dose of DPT rose annually (except for a fluctuation in 1984) from 26% in 1981 to 51% in 1987. Similarly, coverage of the third dose of oral polio (which is generally given concurrently with DPT) rose each year (except for a fluctuation in 1982) from 19% in 1981 to 59% in mid-1988.

One interpretation of this pattern is optimistic. The campaign could actually have strengthened the routine services; if it had, on the other hand, undermined the routine services, any harm was more than offset by the positive contribution of PREMI and earlier campaigns to Ecuador's vaccination programme.

These are, however, alternative explanations of the PAHO coverage data. In late 1986, Ecuador joined PAHO's effort, with its Member countries and international donors, to eradicate wild polio virus from the Americas. The rising coverage of polio and DPT immunizations reflect success due to this effort. On the other hand, the reported coverage rates of the first doses of DPT and polio and rates for BCG and measles have all declined from 1985 to 1987. For example, after the reported measles coverage had risen from 34% of children under 1 year in 1983 to 54% in 1985, it then declined to 46% in 1987. Additional possible explanations of these trends include: strengthening the Ministry's management information system, shifts in priorities regarding vaccinations, and the natural maturation of vaccination programmes in Ecuador and worldwide. As these trends in national coverage rates are affected by so many factors, the long-term impact of campaigns cannot be clearly isolated. Evaluating this impact is further complicated by the changes in campaign services themselves. Ecuador's health officials have gradually streamlined the country's vaccination campaigns. For example, they have shortened three-day rounds into one-day rounds and cut the number of rounds per year from three to two.

Reflecting uncertainty about the long-term value of campaigns, the PAHO Directing Council stated that campaigns are an interim measure to be used until satisfactory vaccination coverage is achieved. It added that later they "should be gradually replaced by regular immunization services performed routinely by health services".[i] The PREMI project, like many campaigns, undertook not only to boost vaccination coverage, but also to change both awareness and practices regarding many child health issues. Acknowledging these goals, Dr R.H. Henderson, Director of WHO's Expanded Programme on Immunization wrote: "... it would take some years before being able to conclude what long-term effect a campaign had, even if one were to be able to objectively define and quantitate such effects as ... raising social consciousness for immunization and other effective interventions" (personal communication, 1986).

Campaigns have been criticized because an investment of their cost (e.g., $1.7 million in Ecuador for 1985–86) in the routine services might have achieved greater results. Although this and other studies report the average cost-effectiveness of routine services, no studies are known of the incremental cost-effectiveness of additional expen-

[h] See footnote *d* on page 653.

[i] **Pan American Health Organization.** *EPI Newsletter* (October 1985).

ditures on routine services. Furthermore, the visibility, novelty, and promise of the campaign approach were key factors in its securing both domestic and foreign funding. It would probably be more difficult for routine services alone to secure this additional funding. The effects of investment to strengthen routine services would probably need time to become apparent. Ministries of health, like other large organizations, generally change slowly.

This study found that the PREMI vaccination campaign was highly effective, and reasonably cost-effective, in the short run. While some indicators show long-term success as well, their interpretation is confused. As national campaigns are unlikely ever to be introduced according to an experimental design, the problem may be insolvable.

The authors recommend that future research must examine where and how campaign efforts should be directed, based on short-run results. Setting priorities will entail comparing the increase in coverage from campaigns between rural and urban areas, the performance of campaign rounds with different frequencies and durations, and different types of media promotion. Standardized, prospective systems of collecting both cost and coverage data would permit the use of more streamlined methods than those in this study. If a country maintains a thorough and reliable system of vaccination statistics, then coverage effects can be easily assessed. Similarly, standardized systems for analysing costs using computer spreadsheets (like "EPI cost" being developed by WHO) would facilitate cost comparisons between the two approaches. In the future, operations research on vaccination strategies may become a routine part of vaccination programmes.

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Résumé

Rapport coût-efficacité des stratégies de vaccination de routine et de vaccination de masse en Equateur

Une enquête nationale sur la couverture vaccinale qui a été menée en juillet 1986 en Equateur et qui a porté sur 3697 enfants a donné l'occasion d'analyser le rapport coût-efficacité des vaccinations de routine effectuées dans les centres fixes et des campagnes de vaccination de masse. Un des principaux objectifs des campagnes était de compléter les services de routine et d'accélérer les activités de vaccination. D'après les résultats de cette enquête, la campagne du Programme pour la réduction des maladies maternelles et infantiles (PREMI) et les campagnes antérieures ont fait passer la proportion d'enfants de moins de cinq ans complètement vaccinés de 43% à 64%. En un an, la campagne du PREMI a permis de vacciner complètement 11% des enfants de moins d'un an, 21% des enfants de un à deux ans et 13% de tous les enfants de moins de cinq ans. En outre, grâce à cette campagne, beaucoup d'enfants ont pu être complètement vaccinés alors qu'ils étaient encore très jeunes et particulièrement vulnérables.

Le coût moyen par dose de vaccin (exprimé en dollars des Etats-Unis au taux de 1985) a été voisin de \$0,29 pour les centres fixes et de \$0,83 pour la campagne du PREMI. Le total des dépenses à l'échelle du pays a été de \$675 000 pour les vaccinations de routine et de \$1 665 000 pour la campagne. Le coût par enfant complètement vacciné s'est établi à \$4,39 pour la vaccination de routine et de \$8,60 pour la campagne. Le coût de chaque décès évité d'environ \$1900 pour la vaccination de routine, \$4200 pour la campagne du PREMI et \$3200 pour les deux programmes combinés. Etant donné que les taux de mortalité de l'Equateur sont plus faibles, le coût de chaque décès évité grâce aux stratégies de vaccination a été plus élevé que celui qui ressort des études comparables menées en Afrique. Bien que leur rapport coût-efficacité soit inférieur à celui des vaccinations de routine, les campagnes de vaccination ont amélioré la couverture vaccinale de façon significative chez les jeunes enfants qui n'avaient pas été atteints par le programme régulier. Le coût des deux stratégies par enfant complètement vacciné se compare favorablement à celui des programmes similaires dans d'autres pays.

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Annex A

Cost of vaccination under routine services

For each fixed site facility sampled, the total and average costs of types of final services, including immunizations, were estimated for the calendar year 1985, based on detailed guidelines (*16*). The average cost of health centres (urban facilities whose scope lies between hospitals and subcentres) was estimated by interpolating values for hospitals and subcentres (see Table 1).

Where possible, costs were assigned directly to the type of service incurring them (e.g., all costs of vaccines were assigned to vaccinations). In addition, shared local facility costs, such as those for administration, were allocated among immunizations and other appropriate services based on the service's proportion of directly assigned costs. Certain supporting costs were deemed to be inapplicable to immunizations. On the other hand, immunizations were charged for a share of time that could not be assigned to any specific service: unknown uses of time and slack time. Costs include all resources used in the health care system, whether or not the MOPH paid for them during the study period.

The direct labour cost for vaccinations was based on the estimate that delivery of each dose required five minutes. Costs of promotion through the media and minor training for routine immunizations at special retreats supported at the national level were estimated from 1986 data provided by INNFA. In cases where promotional efforts covered immunizations, oral rehydration therapy and growth monitoring, one-third of the cost was allocated to immunizations. Six-month values were doubled to yield annual equivalents and deflated to eliminate the 24% inflation in urban consumer prices which occurred between mid-1985 and mid-1986 (Central Bank of Ecuador statistics, 15 January 1987). National promotion costs were allocated to individual facilities according to the number of doses provided.

To compute the average cost per dose for each type of facility, the individual facilities were weighted according to their number of doses. The national average cost per dose was calculated by weighting the average cost for each type of facility by the estimated proportion of doses performed in each type of facility in the country during 1985.[a] This weighting meant that the number of facilities (hospitals, subcentres, etc.) in the sample did not need to be proportional to the number in the country. To estimate the total national cost of routine immunizations of children under 5 years during the year, the overall average cost was multiplied by the total number of EPI vaccinations to children under 5 years at all MOPH establishments (2 286 015).[b] Sample standard errors (computed based on the system of weights) indicate the importance of sampling variation on mean costs.

Several methodological characteristics of the study might have introduced bias, but a series of sensitivity analyses suggested that none distorted the results. Pertinent methodological features that were tested included the following: (1) Sampled provinces had higher-than-average population densities, which provided a greater opportunity for delivering more doses per facility and distributing fixed costs over a greater volume; while a more representative sample theoretically could have produced an average cost up to 26% higher, the data showed no consistent pattern between volume and average cost indicating any bias. (2) Differential costs of brigades that deliver outreach vaccinations were excluded owing to inability to collect data on their costs or activities; their inclusion could have increased the average cost up to 20%. (3) The assumption that each routine immunization required five minutes of the provider's time could be altered; as unaccounted time was included in indirect costs and allocated to the directly assigned activities, including immunizations, there would have been little impact. (4) Cost per dose in the health centres was interpolated between cost per dose in hospitals and health subcentres; the alternative would have been to set the unit cost in health centres as equal to unit costs in hospitals or health centres, which would have, respectively, lowered or raised the national cost of routine vaccinations by 4.4%. (5) Sampling variation could have made the estimates of average cost per dose unstable; based on the normal distribution, the 95% confidence intervals of the mean costs per dose were $0.65 to $1.01 for routine vaccinations and $0.09 to $0.49 for campaign vaccinations and did not overlap.

Annex B

Costs of the PREMI vaccination campaign

For consistency with routine immunizations in fixed facilities, the costs of the campaign were adjusted to 1985 prices. Moreover, similar price scales were used for both strategies to value personnel and vaccines. Time of volunteer personnel was valued at entry level salaries for Ministry personnel.

The 30 facilities were grouped into four types to estimate the campaign costs: hospitals, health centres, subcentres, and health posts. Satellite immunization sites (mobile brigades, schools, and public parks) were included in the total cost of the facility to which they were attached. The average cost per dose for each type of facility for the third round was calculated by dividing the total cost by the number of doses of vaccine provided during the third round. A weighted national average cost was estimated similar to that for the routine programme (see Table 1, page 651).

To determine whether the estimate of costs of the campaign depended critically on the study methodology, the authors conducted a series of sensitivity analyses similar to those for the routine programme. The results remained robust to the following alternative assumptions. (1) Transportation costs for vaccinations might have been underestimated because the third campaign round, from which cost estimates were derived, included two other child survival activities (ORT and growth monitoring), whereas the first two rounds did not; under the most extreme assumption, that transportation costs for vaccinations alone would have been as high as those for all three activities, the cost per dose would have risen by only 29%. (2) Although PREMI

[a] For example, the estimated number of routine doses in hospitals is the number of hospitals times the mean doses per hospital (i.e., 114 × 40 808, or 4 652 112). The estimated number of doses in all facilities is 1217 × 6366 = 7 747 422, so the proportion of doses in hospitals is 0.600 (4 652 112/7 747 422). Thus, the cost per dose in hospital ($0.24) was weighted by 0.600. This weighting compensated for the fact that hospitals were overrepresented in the sample relative to their number in the country. Calculations were performed in sucres and later converted to US dollars.

[b] This analysis excludes doses of DT vaccine (usually given to school-age children beyond the age range for the EPI programme), yellow fever vaccine, and all doses to children over 5 years.

officials said that vehicles were used only for the three-day period of the campaign, allocating 5.5 days of vehicle use would have increased the cost per dose of campaign vaccinations by about 17%; both of these assumptions would magnify the differences in costs between campaign and routine immunizations. (3) The 30 facilities from which campaign costs were estimated had about 10% more doses than the average for the nation; this oversampling of larger facilities may have slightly underestimated the campaign costs by up to 7%. (4) Finally, PREMI sought to increase the demand for ORT, growth monitoring, and vaccinations permanently—not just at the time of a campaign round; the reservoir of consumer knowledge should make both campaign and routine services more effective in the future, thereby lowering the cost per dose. These latter two points would apply equally to the routine strategy, so their relative costs would not be affected.

Annex C

Vaccination coverage

Vaccination status, a major indication of health, was determined by examining the children's and women's vaccination cards whenever possible. For one quarter of the children who did not have a complete card, the interviewer assessed coverage with "verbal histories."

All doses administered during the month of a campaign round were considered to be campaign doses. For multiple-dose vaccines (DPT and polio), only the third dose was analysed for coverage achievement, as three doses are needed for maximum immunity. Analysis of coverage rates for children under one year of age required special treatment because of the disparity in optimum administration ages for BCG, DPT, polio, and measles vaccines. Therefore, overall coverage for children under one year old was calculated as the proportion of vaccinated children between nine and elevent months old. The coverage rate for the final dose of each vaccine was apportioned among the routine, PREMI, and earlier campaign activities based on the share of doses of that vaccine administered by each approach. The coverage rate for fully-vaccinated children was apportioned based on the share of all vaccine doses to a child of that age from each activity.

The number of children in each age group vaccinated during the year 1985–86 from each strategy is the product of the increase in coverage in that age group during the year from that strategy times the number of children in that age group. The population of children under 1 year in 1986 was estimated as 335 100 and that for 1–4-year-old children was 1 164 900 based on the total under-5-years population of 1.5 million reported by UNICEF (*21*). The increase in coverage during the year is identical to the coverage on the survey at the end of the year for children under one and for children vaccinated through the PREMI campaign, as all of their vaccinations had to have been administered within a one-year period (see Table D2, page 662).

For the routine programme, the increase in coverage is one quarter of the difference between the coverage rate in children aged 1–4 years and that in children under 1 year. As the observed level of coverage in an age group spanning four years is a cumulative achievement over the last four years, it is necessary to divide the observed coverage by four. The same procedure was applied to the proportions of children who were fully vaccinated by age group to determine the number of fully vaccinated children by strategy.

Comparison of the number of doses administered through each strategy with the number of FVC produced (see Table 2, page 654) shows that 15 doses were provided per FVC both through routine services (2 300 000 doses divided by 154 000 FVC) and 11 through the PREMI campaign. If no doses were repeated or expended on children who do not attain full vaccination, 8 doses have been required per FVC. The excess over 8 represents doses given to partially vaccinated children, booster doses, tetanus toxoid doses to women, and possible inconsistencies in the tallying and allocation of vaccine doses by age.

Use of coverage surveys to apportion credit among routine immunizations and pre-PREMI and PREMI campaigns required two major assumptions. First, children who received a vaccine dose through a campaign would not have received that dose at all, or at least not at a timely age, if the campaign had not occurred. While the intermittent timing of campaigns and additional data discussed in the conclusions of this paper make this assumption plausible, only a controlled trial (which is impractical for a national programme) could have provided a definitive test. Second, credit for FVC was apportioned on the basis of aggregate statistics for all surveyed children, rather than just fully vaccinated children alone. This method accounts appropriately for the contribution of campaign and routine services for children still completing their vaccinations.

Annex D

Health impacts

To overcome data limitations in estimating health impacts, age was grouped into two categories (less than 1 year, and 1–4 years). The number of deaths and cases averted due to each vaccination strategy was estimated through four steps: (1) estimating the efficacy of the vaccine in each age group; (2) deriving the age-specific incidence and mortality for each of the six EPI diseases among unvaccinated children in each of the two age groups (< 1 and 1–4 years) in 1986; (3) assessing the number of children vaccinated by strategy and by age groups in the year 1985–86 (described in Annex C); and (4) calculating numbers of deaths and cases averted from the previous results.

Vaccine efficacy. Rates of vaccine efficacy (E) for tetanus, pertussis, and measles were taken from the *Reviews of Infectious Diseases* (*15*). The efficacy for BCG vaccinations against tuberculosis, taken from Stead,[c] is also the maximum value from the US Public Health Service (*13*). The efficacy of polio vaccine was estimated by the authors based on *Population Reports* (*12*).

Disease incidence and mortality. To begin estimating mortality rates in unvaccinated children, the officially reported deaths were adjusted for underreporting in each of the two age categories (< 1 and 1–4 years). The expansion factor for each age category was the number of childhood deaths estimated from overall child mortality rates published by UNICEF (*21*) divided by the reported number of deaths from all diseases in children under 5 years in Ecuador published in the country's vital statistics (Table D1). These adjusted mortality rates reflect the mortality experience among a mixture of vaccinated and unvaccinated children. The mortality rates of unvaccinated children were then computed as described below. Table D2 presents the results, along with similarly derived morbidity rates.

The adjusted mortality (M) is a weighted average of the vaccinated and unvaccinated mortality rates (M_v and M_u, respectively). The weights are the proportions of children in each age group who were vaccinated from all strategies combined (v) and unvaccinated ($1-v$), respectively. The mortality rate in the vaccinated group is lower than the mortality rate in the unvaccinated group by the vaccine efficacy (E). Thus,

$$M_v = (1 - E)M_u$$

and

$$M = (1 - v)M_u + v(1 - E)M_u = (1 - vE)M_u.$$

[c] **Stead, W.W.** *Enfermedades por Micobacterias* [Diseases from mycobacteria]. No date, Part 9, section 174, p. 986 (in Spanish).

Table D1: **Derivation of mortality rates in unvaccinated children**

	Tuberculosis	Pertussis	Tetanus	Poliomyelitis[a]	Measles	Total
Reported deaths[b]						
<1 year	17	130	91	1	45	284
1–4 years	34	70	3	8	67	182
Adjusted deaths[c]						
<1 year	36	278	195	2	96	607
1–4 years	64	132	6	16	127	345
Vaccine efficacy	0.80	1.00	1.00	0.99	0.89	N.A.[e]
Coverage by age[f]						
<1 year	0.94	0.32	0.22	0.32	0.44	N.A.
1–4 years	0.96	0.82	0.82	0.82	0.877	N.A.
Unvaccinated mortality rate[g]						
<1 year	43.3	122.0	74.6	0.9	47.1	287.9
1–4 years	23.7	63.0	2.9	7.3	47.4	144.3

[a] Polio "deaths" are death-equivalents, which are the number of reported cases. (The health burden of a clinical case of polio was considered equivalent to a death). Allocation of cases of paralytic polio by age assumes: <1 year, 10%; 1–4 years, 80%; >5 years, 10%.
[b] Pertussis and measles deaths reported are the average of 1985 and 1986 (See footnote *d* on p. 653).
[c] Deaths inflated for underreporting by comparing PAHO[d] and UNICEF (*21*). Deaths from tuberculosis and tetanus (ages 1–4 years) from PAHO.[d] Deaths from tetanus (age <1 year) were considered equal to reported *cases* of neonatal tetanus.[d] Percentage of deaths that were reported were: <1 year = 46.7%; 1–4 years = 52.9%.
[d] See footnote *d* on page 653.
[e] N.A. = not applicable.
[f] Combined coverage from all sources. Tetanus "coverage" of children <1 year old is given by the vaccination rate of pregnant women to protect against neonatal tetanus.
[g] Per 100 000 unvaccinated children per year.

Table D2: **Number of deaths and cases averted**

	Tuberculosis	Pertussis	Tetanus	Poliomyelitis[a]	Measles	Total
Routine services:						
Coverage rates[b]						
<1 year	0.62	0.21	0.15	0.20	0.23	N.A.[c]
1–4 years	0.04	0.08	0.10[d]	0.08	0.08	N.A.
Deaths averted						
<1 year	72	85	38	1	32	228
1–4 years	9	61	3	7	39	119
All ages	81	146	41	8	71	347
Cases averted[e]						
<1 year	2276	589	38	1	29 496	32 400
1–4 years	269	14 505	179	7	13 738	28 697
All ages	2545	15 094	217	8	43 234	61 097
PREMI campaign:						
Coverage rates						
<1 year	0.32	0.12	0.04[d]	0.12	0.21	N.A.
1–4 years	0.05	0.18	0.18	0.19	0.21	N.A.
Deaths averted						
<1 year	37	49	10	0	30	126
1–4 years	11	132	6	16	103	268
All ages	48	181	16	16	133	394
Cases averted						
<1 year	1175	337	10	2	26 931	28 453
1–4 years	321	30 518	320	9	35 699	66 874
All ages	1496	30 855	330	11	62 630	95 327
Both combined:						
Deaths averted						
<1 year	109	135	48	1	62	354
1–4 years	20	193	9	23	142	387
All ages	129	328	57	24	204	741
Cases averted						
<1 year	3451	926	48	1	56 427	60 853
1–4 years	590	45 023	499	23	49 437	95 571
All ages	4041	45 949	547	24	105 864	156 424

[a] Polio "deaths" are death-equivalents, which are the number of cases reported in the Ecuador MOPH's EPI report (February 1987).
[b] Routine services' contribution to coverage achieved in one year. Contribution for ages 1–4 years are one-fourth of the difference between coverage rates for ages 1–4 years and age <1 year, as the additional coverage is the cumulative effect over four years.
[c] N.A. = not applicable.
[d] Coverage applied to children <1 year is that of pregnant women; their total coverage of 22% was allocated among routine services, PREMI, and pre-PREMI based on the proportion of total vaccine doses by each strategy.
[e] In calculating the cases averted, polio cases counted only the paralytic polio cases. All unvaccinated children were assumed to contract measles before age 5 years, so the annual measles incidence is equal to the population under age 1 year. Tetanus incidence for 1984 (based on unpublished WHO document, EPI/GEN/44, 1986). Tuberculosis rate is based on worldwide incidence rates (WHO Media Service, *In point of fact*, No. 46, 1987, unpublished).

The preceding equation is solved for M_u in terms of known variables:

$$M_u = M/(1 - vE).$$

Numbers of deaths and cases averted. The number of deaths averted from each disease in each age group under each strategy is the product: (Number of children vaccinated) $\times M_u \times E$. To determine the number of *cases* averted, M_u is replaced by the incidence in unvaccinated children in each age group. It was assumed that vaccination may reduce the incidence of disease, but has no influence on the severity, duration, or impact of a case once it occurs. Table D2 presents the results.