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Public finance of rotavirus vaccination in India and Ethiopia: An extended cost-effectiveness analysis

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ABSTRACT

Background: An estimated 4% of global child deaths (approximately 300,000 deaths) were attributed to rotavirus in 2010. About a third of these deaths occurred in India and Ethiopia. Public finance of rotavirus vaccination in these two countries could substantially decrease child mortality and also reduce rotavirus-related hospitalizations, prevent health-related impoverishment and bring significant cost savings to households.

Methods: We use a methodology of 'extended cost-effectiveness analysis' (ECEA) to evaluate a hypothetical publicly financed program for rotavirus vaccination in India and Ethiopia. We measure program impact along four dimensions: 1) rotavirus deaths averted; 2) household expenditures averted; 3) financial risk protection afforded; 4) distributional consequences across the wealth strata of the country populations.

Results: In India and Ethiopia, the program would lead to a substantial decrease in rotavirus deaths, mainly among the poorer; it would reduce household expenditures across all income groups and it would effectively provide financial risk protection, mostly concentrated among the poorest. Potential indirect benefits of vaccination (herd immunity) would increase program benefits among all income groups, whereas potentially decreased vaccine efficacy among poorer households would reduce the equity benefits of the program.

Conclusions: Our approach incorporates financial risk protection and distributional consequences into the systematic economic evaluation of vaccine policy, illustrated here with the case study of public finance for rotavirus vaccination. This enables selection of vaccine packages based on the quantitative inclusion of information on equity and on how much financial risk protection is being bought per dollar expenditure on vaccine policy, in addition to how much health is being bought.

1. Introduction

About a third of global diarrhea-related deaths are attributed to rotavirus. In children younger than five years an estimated 4% deaths were the result of rotavirus-related diarrhea in 2010 [1,2]. The large majority of these deaths among under-fives were in low-income populations of Africa and Asia [1,2]. Five countries (the Democratic Republic of the Congo, Ethiopia, India, Nigeria and Pakistan) accounted for more than half of all rotavirus deaths [1–3].

The introduction of rotavirus vaccine into the vaccination schedule of lower income countries might lead to substantial reductions in child mortality and significantly reduce the number of rotavirus-related hospitalizations, as it has been observed in the (high-income) countries where implemented [4]. In sub-Saharan Africa and India, 90% of rotavirus-related hospitalizations occur among children under two years of age [5,6]. Though the efficacy of rotavirus vaccine, a standard two-dose regimen given at 6 and 12 weeks of age [7], has proven lower in the developing

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countries that are highly impacted by rotavirus [7,8],[1] even a partially effective vaccine there could save many lives and bring substantial cost savings to households possibly preventing them from medical impoverishment.

Rotavirus vaccination may be a very cost-effective intervention [9–14] which could save up to 2.5 million lives over the next 20 years in Global Alliance for Vaccines and Immunization (GAVI)-eligible countries [10]. Country-specific benefits from rotavirus vaccination will depend on the specific burden of diarrhea, vaccine price and efficacy, and the targeting of the vaccination programs [9,12,13]. Greater benefit should be expected in low-income countries, primarily because of high mortality levels. Within countries, greater benefit should be expected among the poorest populations who often have higher risks of death, reduced access to effective care, and bear significant economic costs due to disease treatment.

Health interventions such as rotavirus vaccination, and by extension the policy levers that finance and deliver them, have distributional consequences across wealth strata of populations which they target. Early work has shown that universal measles vaccination coverage could substantially reduce income-related mortality differentials in high mortality settings [15]. More recently, Rheingans et al. [16] examined the cost-effectiveness of rotavirus vaccination per income group in selected GAVI-eligible countries, and found it most cost-effective to vaccinate in low-income populations.[2]

Policy choices that affect vaccination coverage include public finance (PF) for routine administration of a specific vaccine, mass campaigns,[3] and conditional cash transfers to encourage utilization [17]. PF policy of vaccine programs has some specific and positive consequences. First, PF increases uptake and leads to widespread health gains. Second, PF can reduce household expenditures on health care and prevent medical impoverishment. Finally, PF can have differential impact across a population by level of income [18].

In this paper, we apply a methodology of extended cost-effectiveness analysis (ECEA) [18] to evaluate the consequences of vaccine policy in each of the dimensions described above. We illustrate our approach with the case study of PF for rotavirus vaccination in two countries with substantial rotavirus burden, India and Ethiopia. Both countries have substantial rotavirus burden, yet differ significantly epidemiologically and economically. In order to make decisions on the introduction of new vaccines, Indian and Ethiopian policymakers need estimates of vaccination costs and outcomes, which differ across socio-economic groups. Distributional aspects have implications for decisions about where to invest first. The ECEA approach adds distributional consequences and financial risk protection (FRP) considerations to the decision criteria. It enables selection of vaccines based on quantitative inclusion of how much FRP is provided, as well as how much health is gained, per dollar expenditure on a policy [18].

[1] Many hypotheses have been suggested to explain this difference in efficacy of live oral rotavirus vaccines between developing and developed countries, including breastfeeding practices, micronutrient malnutrition, or differences in rotavirus epidemiology [7]. This difference is most likely linked to the levels of antibody transferred from the mother to the infant which can inhibit the infant immune response to the vaccine.

[2] Given the same vaccination cost per income group.

[3] Mass campaigns are commonly implemented for vaccines such as measles or polio but may not be appropriate for rotavirus vaccine which has to be given within a very specific time schedule.

2. Methods

We evaluate PF for rotavirus vaccination at survey-reported levels of DPT2 (2nd dose of Diphteria-Pertussis-Tetanus vaccine)[4] coverage in India and Ethiopia, drawing from standard cost-effectiveness methods [21]. In each country, we follow a hypothetical cohort of 1,000,000 births over the first five years of life. Rotavirus-related mortality outcomes and household expenditures are estimated for this cohort. The five-year horizon captures all relevant effects with simplicity: one cohort is modeled, and under-five children constitute the population group in which outcomes mostly occur and for whom data (e.g. burden of disease) is available. We adopt a societal perspective and consider the vaccination costs borne by providers (e.g. governments), separated from the rotavirus-related expenditures borne by patients and their families.

We estimate the level and distribution (across income groups) of the rotavirus deaths averted; the households' expenditures (direct medical costs and transport costs) related to rotavirus treatment averted ('private expenditures crowded out') and the costs needed to sustain the program (vaccination costs borne by the government); and the financial risk protection afforded by the program measured by an imputed money-metric value of 'insurance' provided, which we describe in detail in the supplementary data (Section 1.3).

2.1. Data sources

Values for all parameters are listed (Table 1). Before program introduction, individuals pay out of pocket for rotavirus treatment and the demand (utilization) and cost of this service vary by income group [20,23–32]. Vaccine effectiveness is assumed to be 43% and 49% for India and Ethiopia, respectively (consistent with trial data from Bangladesh and Malawi [33,34]); vaccine price is \$2.50 per dose as currently procured to the GAVI Alliance [35]. We assume the program would achieve a similar coverage across all income groups equal to mean DPT2 coverage reported from survey data [19,20],[4] the incremental cost of vaccine administration to be \$0.25 per dose based on the World Health Organization Global Immunization Vision and Strategy costing model [10,36].

2.2. Rotavirus deaths averted

The model follows a birth cohort of 1,000,000 individuals over five years and uses an indicator of relative rotavirus mortality ('risk index') varying by income group in order to quantify the reduction in under-five mortality due to rotavirus, in each income group, an approach which was implemented elsewhere [16]. Before the vaccination program, the rotavirus burden of disease is distributed across income groups, based on the risk index specified by income group (Table 1). The approach is static; in the case of rotavirus, vaccination may provide some protection to unvaccinated individuals due to herd immunity, which has been documented in a few (high-income) countries [37–39]. In section 3.2.3, herd effects are imputed into our model in order to estimate possible additional benefits of indirect protection due to vaccination.

[4] Survey-reported DPT2 coverage [19,20] was used to estimate the fraction of newborns that would receive the two doses of rotavirus vaccine. DPT2 coverage is meant to capture a realistic country health system capacity and to represent achievable vaccine coverage. DPT2 coverage was 76% in India in 2008 [19] and 52% in Ethiopia in 2011 [20].