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Comparing the health and social protection effects of measles vaccination strategies in Ethiopia: An extended cost-effectiveness analysis

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ABSTRACT

Vaccination coverage rates often mask wide variation in access, uptake, and cost of providing vaccination. Financial incentives have been effective at creating demand for social services in a variety of settings. Using methods of extended cost-effectiveness analysis, we compare the health and economic implications of three different vaccine delivery strategies for measles vaccination in Ethiopia: i) routine immunization, ii) routine immunization with financial incentives, and iii) mass campaigns, known as supplemental immunization activities (SIAs). We examine annual birth cohorts of almost 3,000,000 births over a ten year period, exploring variation in these outcomes based on economic status to understand how various options may improve equity. SIAs naturally achieve higher levels of vaccine coverage, but at higher costs. Routine immunization combined with financial incentives bolsters demand among more economically vulnerable households. The relative appeal of routine immunization with financial incentives and SIAs will depend on the policy environment, including short-term financial limitations, time horizons, and the types of outcomes that are desired. While the impact of financial incentives has been more thoroughly studied in other policy arenas, such as education, consideration of this approach alongside standard vaccination models such as SIAs is timely given the dialog around measles eradication.

1. Introduction

Vaccination has long been regarded as an effective and inexpensive means of improving mortality and morbidity in developing countries (Bloom et al., 2005). Despite the proven benefits, challenges remain in improving and maintaining coverage. One dilemma countries face in the battle against vaccine-preventable diseases is the choice between improving coverage of existing vaccines and rolling out new vaccinations to the current pool of reached individuals. Embodied in this tension is the importance placed on addressing disparities in health care access and reaching out to marginalized populations (Delamonica et al., 2005).

While vaccination remains an individual decision, governments and donor agencies have mounted a variety of outreach efforts to increase access to and demand for vaccination (Duclos et al., 2009; Organization & UNICEF, 2001; Strebel et al., 2003). These efforts may in part be driven by the oft-cited positive externalities of vaccination, and the broader links between population health and economic growth (Andre et al., 2008; Bärnighausen et al., 2011; Bloom et al., 2005; Ehreth, 2003; Stack et al., 2011). Supplementary immunization activities (SIAs), or mass campaigns, provide supplemental doses in addition to the doses prescribed in the standard vaccination schedule (World Health Organization, 2009). These outreach efforts to increase not only coverage but also the intensity of coverage are especially important in the context of disease elimination goals, such as the regional measles elimination efforts led by the World Health Organization (WHO) (Christie and Gay, 2011; Organization, 2011; Strebel et al., 2011).

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The key to these outreach efforts is correctly matching the target population with a strategy that will increase demand for vaccination. Coverage is typically geographically clustered, and high-coverage areas are both observably and unobservably different from low-coverage areas (Morris et al., 2013). For example, remote areas with limited health care access are less likely to be reached through routine immunization (Okwaraji et al., 2012), and mass campaigns or canvassers may be more appropriate in these settings than in more urban environments where media campaigns may have broader reach and routine care is more accessible (Kirigia and Barry, 2008). This geographic variation in demand creates variation in the optimal outreach strategy based on the existing level of coverage. Thus, approaches that were successful early on, for example in improving coverage from 15% to 25%, may no longer be optimal when attempting to boost coverage from 80% to 90%. This variation in the relative value of different strategies reflects changes in both the costs of the strategies and their marginal impact on demand. This is partly due to sociodemographic and geographic shifts in the unvaccinated population as the coverage rate increases; demand-side factors such as parents' education have been shown to affect the demand for vaccination (Xie and Dow, 2005).

Thus, policymaking around improving vaccination coverage must consider not only the supply of vaccinations, which includes the delivery mechanism, but also the demand for these services. Other types of social interventions, such as those with educational goals, have commonly linked socially desirable goals with financial incentives to create demand. Conditional cash transfers (CCTs) are one approach that uses this mechanism by making cash or other transfers to enrollees who complete certain requirements. These programs are typically means-tested or proxy means-tested, using indicators to capture characteristics reflective of economic status such as education, housing quality, and asset ownership (Australian Agency for International Development, 2011). These programs have largely been undertaken in Latin America, including high-profile programs such as Oportunidades in Mexico and Bolsa Familia in Brazil (Handa and Davis, 2006). Typically, these larger-scale programs include educational requirements, such as school enrollment and attendance, as well as health stipulations, such as well-child visits and completed vaccinations. The motivation for these cash transfers is both outcome-specific, in creating demand for worthwhile health and social services, and broadly welfare-oriented, in more generally attempting to break the poverty cycle (Ranganathan and Lagarde, 2012). Improvements in vaccination coverage have been associated with CCTs in Colombia, Honduras, Mexico, and Nicaragua, though there is variation in the time frame, age range, and specific vaccinations where impact was identified (Barham et al., 2007; Barham and Maluccio, 2009; Lagarde et al., 2007; Ranganathan and Lagarde, 2012). Transfer sizes in these programs varied significantly, from 10% to 30% of annual mean household consumption, and all programs had stipulations regarding both school attendance and preventive health care. A randomized controlled study of an immunization-specific incentive program in India that used non-cash transfers found modest effects on immunization rates (Banerjee et al., 2010).

Vaccine delivery strategies have the potential to effect change across multiple social domains. The fundamental health impact is a function of either improving access, in the case where there is insufficient supply, or incentivizing uptake, in the case of lackluster demand. Financial benefits may be realized through averted household health expenditures, or, in the case of financial incentives, additional income. This increase in household resources can potentially have long-term implications for economically vulnerable households by avoiding the poverty trap of poor health and even providing them the capital to move out of poverty.

This paper evaluates three different measles vaccine delivery strategies in Ethiopia using extended cost-effectiveness analysis (ECEA) (Verguet et al., 2015a,b,c; Verguet et al., 2013b). Specifically, we examine the health, financial, and social implications of routine immunization programs, SIAs, and routine immunization with financial incentives. As of 2009, routine services provided coverage to 56% of the population, with rates as low as 30% in the rural region of Affar and as high as 90% in Addis Ababa (Central Statistical Agency (Ethiopia) & ICF International, 2011). Lower rates are evident in more rural areas, where 80% of the population live (Commission, 2008). In addition to routine immunization, Ethiopia has implemented SIAs since 2002 (Mitiku et al., 2011). Given the distribution of various characteristics that affect the ease of supply and the elasticity of demand for vaccination, ECEA is an appropriate method because it considers the distributional impacts of the various strategies. The findings will thus support tailoring the approach to the target population.

2. Methods

ECEA extends cost-effectiveness analysis (CEA) by considering additional, policy-relevant metrics that account for the economic and social effects of poor health (Verguet et al., 2015a,b Verguet et al., 2013b). Thus, rather than simply conducting an economic evaluation of measles vaccination, this study looks at this intervention in the context of three different policy instruments. The broader household and economic effects of these policies are evaluated, including deaths averted, household expenditures averted and financial risk protection (FRP) provided, and government costs. There is an emphasis on the distribution of effects across income quintiles, which speaks to the equity impacts of the different approaches.

2.1. Mortality distribution

Most evidence on child mortality inequalities is not disease-specific, as reported in the Demographic and Health Surveys (DHS) (Central Statistical Agency (Ethiopia) & ICF International, 2011). However a few studies highlight particular cases; for example, Rheingans et al. (2012) estimated rotavirus-specific mortality in 25 GAVI-eligible countries. In this vein, we estimate measles mortality by income group for Ethiopia using a similar disease-focused methodology. Specifically, we distribute the total under-five deaths due to measles using a ‘risk index’ that varies between income groups: we estimate a relative risk ratio in dying from measles between two income groups I and J as proxied by:

$$\frac{R_I}{R_J} \sim \frac{5q0_I \times \left(1 - Cov_I V_{eff}\right)}{5q0_J \times \left(1 - Cov_J V_{eff}\right)}, \quad (1)$$

where $5q0_I$ is the under-five mortality rate in income group I, Cov_I is the coverage of the first dose of measles vaccine (MCV1) in income group I, as indicated by the DHS (Central Statistical Agency (Ethiopia) & ICF International, 2011), and V_{eff} is the effectiveness for MCV1 (Sudfeld et al., 2010). The risk index (e.g. RJ) in equation (1) is estimated as an average of a proxy for the relative probability of being infected with measles (i.e. not being effectively vaccinated) and a proxy for the relative probability of dying from measles (i.e. captured by under-five mortality). This approach to representing the risk differentials across quintiles assumes that, for each quintile, the risk of infection is proportional to within-quintile vaccination coverage, implying no indirect protection. Likewise, it is also assumed that the case fatality rate of measles is proportional to the under-5 mortality rate. The relative risk ratio between quintiles enables distributing the total under-five deaths due to measles in

Table 1
Parameters used for the economic evaluation of measles vaccination strategies in Ethiopia.

Parameter	Value	Sources
Under-5 deaths due to measles 2010	10,450 per income group (from poorest to richest): 3154; 2470; 2099; 1939; 787	Liu et al. (2012); Authors' estimates based on Central Statistical Agency (Ethiopia) & ICF International (2011)
Relative risk ratio of mortality, from poorest to richest (income quintile 1–5)	1.51; 1.18; 1.00; 0.93; 0.38	Based on Central Statistical Agency (Ethiopia) & ICF International (2011) and applied to total under-5 deaths due to measles
MCV1 effectiveness	0.85	Sudfeld et al. (2010)
SIA effectiveness	0.95	Sudfeld et al. (2010)
Coverage of measles vaccine (MCV1), from poorest to richest (income quintile 1–5), before any program	45%; 52%; 52%; 56%; 80%	Central Statistical Agency (Ethiopia) & ICF International (2011)
Gradual annual coverage of MCV1 after P1	1% per year, across all income groups	Authors' assumptions
Gradual annual coverage of MCV1 after P2	1% per year, across all income groups	
Coverage increase of MCV1 after P2, through financial incentive	10% in bottom two income quintiles	
SIA coverage after P3	90% across all income groups	
Inpatient visit cost	$17.69	Based on Stack et al. (2011); World Health Organization (2002)
Outpatient visit cost	$1.77	
Inpatient visit cost paid out-of-pocket	$6.01	Authors' assumptions based on Global Health Expenditure Database (2012)
Outpatient visit cost paid out-of-pocket	$0.60	
Transport costs	$8.37	World Bank Ethiopia: A country status report on health and poverty, Volume 2, Main Report. The World Bank: Washington, DC; (2005).
Probability of inpatient visit	0.02 per measles case	Authors' assumptions based on Bishai et al. (2010)
Probability of outpatient visit	0.10 per measles case	
MCV1 cost per child immunized	$1.22	Griffiths et al. (2009)
SIA cost per child immunized	$1.05	Levin et al. (2010)
Amount of financial incentive	$14	Authors' assumptions based on (Ranganathan and Lagarde (2012))
Administrative costs for P2	10% of total vaccination costs	Authors' assumptions based on Grosh (2008)
Ethiopia's gross domestic product per capita	$360	World Development Indicators (2013)
Ethiopia's Gini index	0.30	

P1, gradual increase of MCV1 of 1% per year; P2, gradual increase of MCV1 of 1% per year supplemented by financial incentives to the bottom two income quintiles; P3, supplemental immunization activity.

each of the five quintiles. Table 1 presents the resulting risk estimates and ensuing distribution of measles mortality across the different income groups. These mortality 'gradients' are used as baseline estimates in our subsequent distributional analysis for measles deaths.

2.2. Evaluation of measles vaccination programs

We examine annual birth cohorts of 2,970,200 over a ten year period (United Nations Population Division Department of Economic and Social Affairs, 2013). We evaluate three measles vaccination programs: incremental increases in MCV1 (P1); incremental increases in MCV1, supplemented by financial incentives (FIs) for the bottom two income groups conditional on obtaining MCV1 (P2); supplemental immunization activity (SIA) of a supplementary dose of measles vaccine, offered to children aged 6-59 months-old (P3). For P1, we assume the program would increase current coverage levels by 1 percentage point per year over ten years for each income group (Central Statistical Agency (Ethiopia) & ICF International, 2011). For P2, we assume the program would increase current coverage levels by 1 percentage point per year over ten years for each income group, supplemented by a fixed 10 percentage point increase in the bottom two income groups who would be the groups receiving the FIs. Ten percentage points increase is meant to capture an achievable coverage for the health system given that current routine coverage levels are low (Central Statistical Agency (Ethiopia) & ICF International, 2011). For P3, we assume that over 10 years there would be two SIAs reaching about 90% of children aged 6–59 months, consistent with the frequency and high coverage of SIA observed in many sub-Saharan African countries (Masresha et al., 2011).

For P1 and P2, we follow Ethiopia's births cohort (almost 3,000,000 live births (United Nations Population Division Department of Economic and Social Affairs, 2013)) over the first five years of life. For P3, we follow Ethiopia's 6–59 months old population up to age five. Measles-related mortality outcomes and measles treatment expenditures averted are estimated for these population groups. The five-year age horizon captures all relevant effects with simplicity: the relevant populations are 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 and measles treatment costs borne by the government, separated from the measles-related OOP expenditures (both treatment and transport) borne by patients and their families.

Using baseline information about measles prevalence and measles vaccination coverage by income quintile, for each vaccination program we estimate the level and distribution (across income groups) of the measles deaths averted; the households' expenditures (direct medical costs and transport costs) related to measles treatment averted, the costs to sustain the program (vaccination costs borne by the government) and the measles treatment costs averted from the government's perspective; and the FRP afforded by the program measured by an imputed percent change in individual income after implementation of either vaccination program. Ethical approval was not required because this study used publicly available secondary data that did not contain any identifiable private information.

2.3. Data sources

Values for all parameters are listed (Table 1). Before program introduction, individuals pay out of pocket for measles treatment and the cost of this service is assumed to be of about a third of the total healthcare treatment costs (Global Health Expenditure Database, 2012). Vaccine effectiveness is assumed to be 85% for MCV1 and 95% for SIAs, respectively (Sudfeld et al., 2010); the higher efficacy for SIAs reflects the fact that this platform tends to vaccinate older children (those older than twelve months of age). All costs are expressed in 2012 US$ using Ethiopia's consumer price index (World Development Indicators, 2013). Per child immunized, MCV1 vaccine price is about $0.58 and MCV1 cost of delivery is about $0.64 (Griffiths et al., 2009); SIA delivery cost is about $1.05 (Levin et al., 2010). For each incremental child immunized with MCV1, we assume an additional cost of $0.09 if MCV1 coverage is below 80% and of $0.19 if MCV1 coverage is above 80% (Levin et al., 2010). These costs strictly reflect the direct costs associated with the program, and do not capture opportunity costs or other indirect costs.

2.4. Measles deaths averted

The model follows the country birth cohort (or 6-59 months-olds) up to age five, and uses the indicator of relative measles mortality (risk index) varying by income group in order to quantify the reductions in under-five mortality due to measles, an approach which was implemented elsewhere (Rheingans et al., 2012). Specifically, we use a measure of annual deaths due to measles among those ages 1–59 months of age (Liu et al., 2012). Before each vaccination program, the measles burden is distributed across income groups, based on the risk index specified by income group (Table 1). The approach is static; in the case of measles, vaccination may provide some protection to unvaccinated individuals due to herd immunity. Dynamic modeling capturing herd effects and seasonality could address these issues (Anderson et al., 1991; Keeling and Rohani, 2008).

2.5. Government costs

From the government's perspective, we estimate the total costs of each vaccination program, depending on the program implemented. P1 and P3 delivery costs have been described above. For P2, the implementation of a financial incentive is assumed to lead to additional administrative costs estimated at 10% of total vaccination costs, based on assessments from other programs (Grosh, 2008).

2.6. Consequences for households and financial risk protection afforded

From the patient perspective, we estimate (by income group) the amount of household expenditures averted for measles treatment following each program introduction. They represent cost savings from the household perspective. In Ethiopia, for the populations followed up to age five, measles-related expenditures borne by families, with and without vaccination, are estimated and depend on probabilities of outpatient/inpatient visits for measles-related outpatient/inpatient visits. Direct medical costs from outpatient/inpatient visits and transport costs are included. Waiting time and travel time are not included. Informal medical treatment costs, and earning and productivity losses are excluded.

Subsequently, we quantify the FRP benefits brought to households by each program in dividing the expected private expenditures averted by individual income. An individual income distribution is proxied while using a Gamma distribution based on country gross domestic product (GDP) per capita and Gini coefficient (Salem and Mount, 1974; World Development Indicators, 2013), the latter of which describes the distribution of income by measuring income inequality. The financial incentive given to individuals in the bottom two income quintiles is set at $14, representing about 10% of an individual's income in the bottom income quintile (Ranganathan and Lagarde, 2012).

2.7. Sensitivity analysis

We checked the robustness of our findings using both one-way and multivariate sensitivity analysis. For one-way sensitivity analyses, we individually varied parameters for costs of treatment and costs of MCV1 and SIA by ± 50%. These parameters were chosen for univariate sensitivity testing because they exploit the differences across the intervention strategies, which is one focus of this study. In addition, a probabilistic, multivariate sensitivity analysis allowed all parameters to vary simultaneously, which is a standard approach to sensitivity analysis using Monte Carlo simulations. Specifically, we used Monte Carlo simulations ($n = 100{,}000$ trials) where all key parameters (cost inputs, amount of financial incentive, measles mortality, measles case fatality rate, probability of inpatient/outpatient visit) were varied simultaneously. This multivariate sensitivity analysis allowed the determination of 95% uncertainty ranges, which are reported with the results. This multivariate sensitivity analysis was performed using Gamma distributions for all cost inputs, amount of financial incentive, measles mortality input and Beta distributions for measles case fatality rate, probability of inpatient/outpatient visit. All input means were given in Table 1 while all standard deviations were assumed to be ± 20% of the input means, except for the amount of financial incentive, measles mortality, case fatality rate and probability of inpatient/outpatient visit whose standard deviations were fixed at ± 50% of the input means.

3. Results

Table 2 summarizes the health and financial implications of each vaccination strategy, including the overall impact and the impact by quintile. The largest number of deaths was averted under SIAs (39,700), while routine immunization with financial incentives averted more than twice as many deaths as the routine immunization without financial incentives (10,300 vs. 4900). This gap was due to sharp declines in the lower two income quintiles, the target group for the incentives; in these groups, deaths averted were almost three times higher under incentives as compared to routine immunization offered without incentives. Costs, not surprisingly, increased with coverage and the intensity of effort. The incentive option ($22,590,000) was estimated to increase costs ten-fold over the standard routine immunization offering ($2,158,000). The most expensive undertaking was the SIAs, at over $23 million.

Household expenditures averted were another outcome in which SIAs had a greater impact. Their four-fold advantage in averted household expenditures is a natural consequence of the higher number of individuals reached. This relationship also plays out when comparing routine immunization with and without financial incentives; expenditures averted are almost three times higher for the lower two quintiles under the incentive option due to a similar increase in coverage.

The defining strength of routine immunization with financial incentives is the change in expected household income. The financial transfer augments income in the lower two income quintiles, leading to 10.5% and 6.0% increases in the first and second quintiles, respectively. The other two delivery mechanisms achieved expected changes in household income of less than 0.2%.

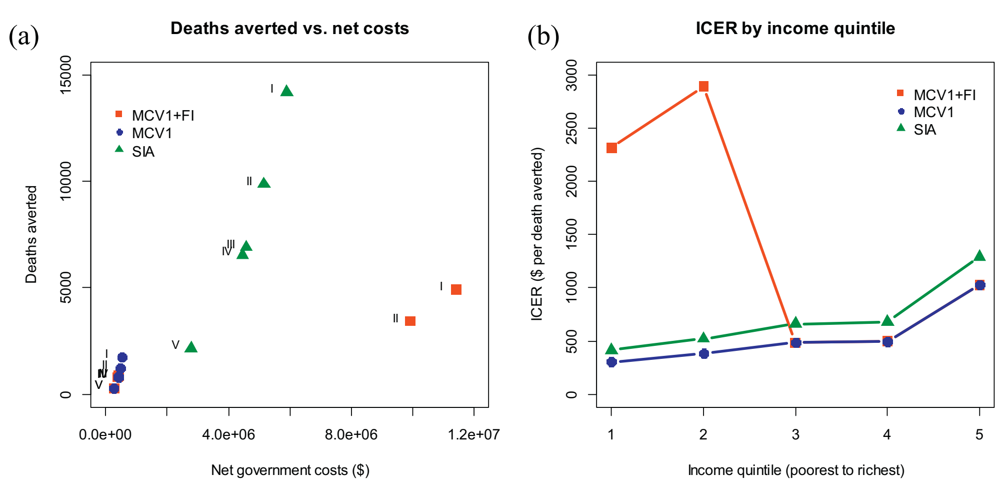
Finally, the incremental cost-effectiveness ratios (ICERs) balance the health and government financial implications of each option to present the cost per death averted. This is lowest for routine immunization without financial incentives and highest for the routine option with financial incentives.

The findings of the economic evaluation (Table 2) suggest that the various delivery options are associated with strikingly different benefits and costs, and this contrast is emphasized in Fig. 1. Routine

Table 2
Extended cost-effectiveness analysis results for each measles immunization program, per income quintile: deaths averted, vaccination costs, household out-of-pocket expenditures averted, percent change in expected income, and incremental cost-effectiveness ratio.

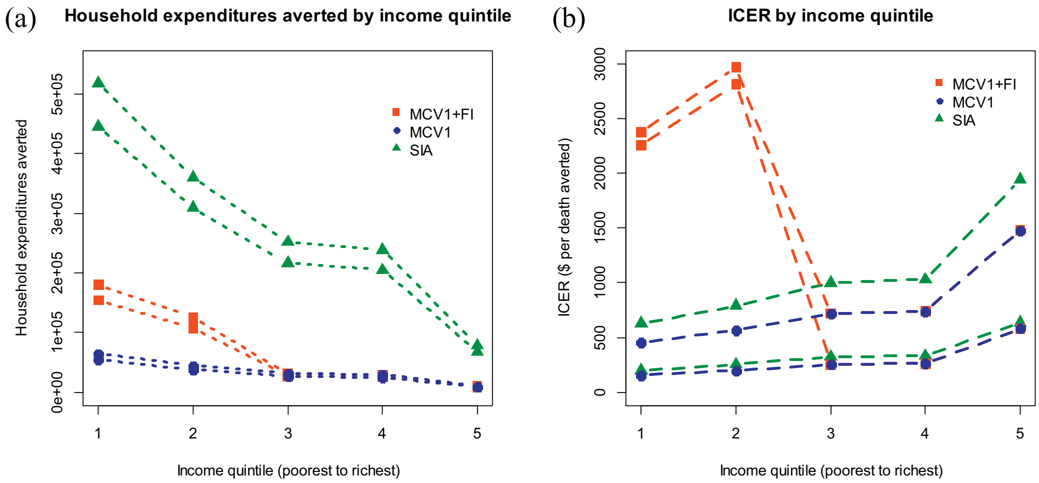
Routine immunization						
Income group	I	II	III	IV	V	Total
Deaths averted	1749 (982–2727)	1216 (687–1892)	851 (482–1331)	805 (454–1256)	264 (150–413)	4885 (3751–6199)
Vaccination costs (thousands of $)	557 (458–666)	483 (396–578)	426 (351–510)	415 (341–496)	276 (231–326)	2158 (1779–2575)
Household expenditures averted (thousands of $)	59 (25–134)	41 (17–93)	29 (12–65)	27 (12–62)	9 (4–20)	165 (82–342)
Percent change in expected income	0.021 (0.009–0.046)	0.009 (0.004–0.021)	0.005 (0.002–0.012)	0.004 (0.002–0.009)	0.001 (0.0005–0.003)	0.006 (0.003–0.012)
Incremental cost-effectiveness ratio ($ per death averted)	303 (179–565)	382 (228–705)	486 (291–893)	500 (301–922)	1029 (629–1870)	427 (312–586)
Routine immunization supplemented by financial incentives						
Group	I	II	III	IV	V	Total
Deaths averted	4929 (2768–7687)	3426 (1935–5332)	851 (482–1331)	805 (454–1256)	264 (150–413)	10,276 (7483–13,611)
Vaccination costs (thousands of $)	11,499 (6772–17,553)	9974 (5874–15,225)	426 (351–510)	415 (341–496)	276 (231–326)	22,590 (13,754–33,910)
Household expenditures averted (thousands of $)	167 (70–377)	116 (49–262)	29 (12–65)	27 (12–62)	9 (4–20)	348 (168–731)
Percent change in expected income	10.534 (5.974–16.3)	5.969 (3.382–9.284)	0.005 (0.002–0.012)	0.004 (0.002–0.009)	0.001 (0.0005–0.003)	2.062 (1.170–3.205)
Incremental cost-effectiveness ratio ($ per death averted)	2318 (1154–4734)	2896 (1442–5874)	486 (291–893)	500 (301–922)	1029 (629–1870)	2183 (1227–3663)
Supplemental immunization activities						
Group	I	II	III	IV	V	Total
Deaths averted	14,216 (7984–22,169)	9882 (5582–15,381)	6918 (3918–10,817)	6544 (3690–10,211)	2149 (1217–3358)	39,708 (30,486–50,384)
Vaccination costs (thousands of $)	6117 (4957–7411)	5306 (4299–6427)	4681 (3793–5671)	4557 (3692–5520)	2809 (2276–3403)	23,470 (19,017–28,432)
Household expenditures averted (thousands of $)	481 (202–1086)	335 (140–756)	234 (99–528)	222 (93–501)	73 (31–165)	1345 (664–2784)
Percent change in expected income	0.040 (0.017–0.090)	0.018 (0.008–0.041)	0.010 (0.004–0.023)	0.008 (0.003–0.017)	0.002 (0.001–0.005)	0.012 (0.006–0.024)
Incremental cost-effectiveness ratio ($ per death averted)	415 (246–775)	522 (311–959)	662 (395–1213)	681 (409–1254)	1291 (780–2351)	576 (413–801)

Note: all costs are expressed in 2012 US$; 95% uncertainty ranges extracted from the multivariate sensitivity analysis are given in parentheses.



MCV1 refers to routine immunization with and without financial incentives (FI), and SIA refers to supplemental immunization activities

Fig. 1. Extended cost-effectiveness analysis results for each immunization program, per income quintile: (a) deaths averted vs. net programmatic costs; (b) incremental cost-effectiveness ratios (ICERs). I = Poorest, II = Poorer, III = Middle, IV = Richer, V = Richest.



Dashed lines indicate variation in outcome when relevant costs (treatment costs in (a), vaccination costs in (b)) are varied by +/- 50%; MCV1 refers to routine immunization with and without financial incentives (FI), and SIA refers to supplemental immunization activities

Fig. 2. Effect of varying costs on outcomes across vaccination strategies: (a) household expenditures with varying treatment costs; (b) ICERs with varying vaccination costs.

immunization with financial incentives and SIAs are most similar in terms of the magnitude of investment required, and their benefits are both dramatic and divergent. SIAs achieve a greater health impact across all quintiles, while the routine immunization with financial incentives results in more modest health gains overall but did create additional demand in households in the lower two quintiles, which ultimately generated dramatic welfare improvements through increased income due to the incentives.

Univariate sensitivity analyses, shown in Fig. 2, mostly preserved the relationships among the interventions. Household expenditures were relatively unaffected by uncertainty in treatment costs. The relative magnitude of the ICERs across the delivery platforms was sensitive to uncertainty in vaccination costs; while still much higher for the routine immunization with financial incentives option among the lower two income quintiles due to the transfer involved, the relative cost per death averted is naturally sensitive to the cost of the respective interventions. For example, while in the baseline scenario SIAs had a higher ICER than the routine and financial incentives scenarios for the three highest income quintiles, significant increases in the cost of MCV1 or decreases in the cost of SIAs reversed that relationship.

4. Discussion

The results suggest that there is no single superior strategy; the relative value of these approaches is dependent on the priorities of policymakers. Timing influences these preferences in several ways. Practically, the cost burdens of these strategies have different time dynamics. SIAs, conducted cyclically, require significant intense investment for each cycle, whereas adding financial incentives to routine immunization is likely to require more evenly distributed investment over time. Thus, preferences around these two approaches are a function of more than just policymaker preference, and will also be influenced by practical limitations such as short-term affordability and resource constraints.

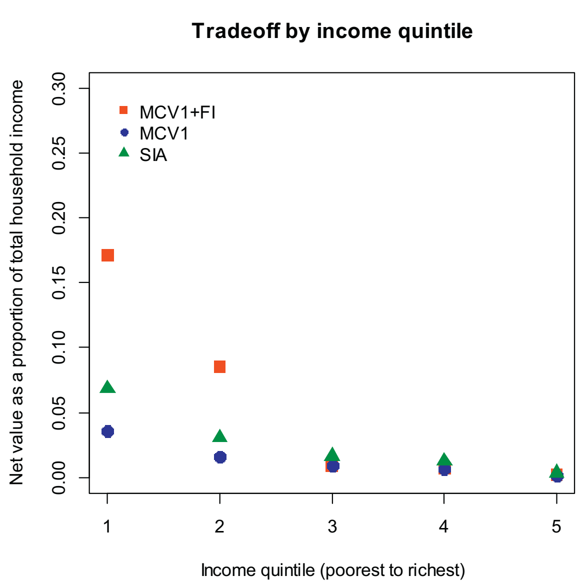
Another determinant of the relative appeal of SIAs and routine immunization with financial incentives is the timing of the benefits. The impact of SIAs will necessarily be felt more immediately, as they have demonstrated success in rapidly boosting vaccination coverage. A similar investment in routine immunizations with financial incentives will achieve a smaller boost in vaccination coverage but has the potential for greater social impacts by clustering demand creation among more vulnerable households. The broader social benefits of financial incentives will take longer to accrue and will manifest in more diverse ways. This is a natural consequence of the design of this type of demand-side approach, in which the transfer not only offsets the cost of procuring the vaccination, but also more broadly empowers families economically. This transfer could be re-invested in health, education, or physical capital, all of which would generate less immediate payoffs. Thus, the discount factor attached to this type of policy decision is a significant determinant of the value of long-run benefits relative to more immediate payoffs.

In addition, if value is defined specifically in terms of vaccination coverage gains then SIAs would clearly offer a better return; however, if value is allowed to be multi-faceted, the use of financial incentives becomes more attractive since the potential health, human capital and economic benefits would receive more weight. In addition, bolstering routine immunizations with financial incentives may represent an investment in the broader health system, while mobilizing the workforce to conduct SIAs might have a detrimental impact on provision of other health services (Griffiths et al., 2011; Hanvoravongchai et al., 2011; Verguet et al., 2013a). Thus, these two strategies may have different profiles in terms of their impact on the health system, one which mirrors the tension between vertical and horizontal health interventions. These considerations may be summarized as the scope of impact and the scope of investment, and they will largely be a function of the policy environment.

Despite stark differences in timing of costs and benefits and type of benefits realized, SIAs and financial incentives have similar distributional properties. While the use of financial incentives is clearly designed to create demand and mobilize lower-income households, SIAs have also been found to improve equity (Vijayaraghavan et al., 2007). This is largely attributed to the inverse correlation between health care access and socioeconomic status; SIAs directly mediate the proximity barrier. In addition, both approaches to vaccination can be expanded to include additional health interventions. Financial incentives have traditionally been attached to a bundle of services, and thus may impact not only vaccination rates but also other healthcare services, such as routine check-ups, and educational outcomes, such as school attendance. SIAs can be similarly expanded to improve access to not only vaccinations, but also interventions such as bednets, vitamin A supplements, and deworming (Grabowsky, et al., 2005a; Grabowsky, et al., 2005b; Johri et al., 2013), which would diminish the previously mentioned concern about this strategy diverting resources from existing health services.

The comparative results suggest a tradeoff between ICER maximization and distributional effects that prioritize health and financial gains in poorer households. One way to represent this tradeoff in a single indicator is to calculate the net monetary value of each intervention relative to total household income. The monetary value of each death is based on the value of a statistical life, using the standard approach of converting the United States-derived value to an Ethiopia equivalent using the ratio of their GDP per capita and an income elasticity of 1.5 (Viscusi and Aldy, 2003). Fig. 3 presents this indicator, by quintile, for each intervention. This measure suggests that financial incentives offer the most relative value to poorer households, those who are eligible for the incentive, while SIAs deliver the highest relative value for higher-income households.

Our findings rely on a static model of disease transmission. One limitation of this approach is that it does not consider indirect protection or herd immunity. For example, herd immunity may be relevant at high levels of coverage, such as those achieved in the highest income quintile in P1 and P2. If transmission between income quintiles is common, then vaccination may have a relatively greater impact among the lower income quintiles through herd immunity as a result of the higher vaccination rates in the higher income quintiles. Conversely, if transmission is confined within income quintiles, the disparities between quintiles may increase as the indirect benefits remain concentrated within the upper quintiles. However, we had no empirical basis for understanding and informing transmission between quintiles.



MCV1 refers to routine immunization with and without financial incentives (FI), and SIA refers to supplemental immunization activities

Fig. 3. Net monetary value of interventions relative to household income, by quintile.

This comparison of strategies to boost measles immunization coverage is timely given the momentum behind measles eradication. While the early part of the last decade saw targets to dramatically reduce measles-related deaths, there also has been a substantial push to aim for a full eradication of measles (Strebel et al., 2011; Quadros, 2004; World Health Organization, 2010). This type of goal will require substantial additional investment in measles immunization, and this paper presents two very different approaches to bolstering coverage rates. While SIAs are a more traditional approach to improving vaccine coverage, financial incentives have demonstrated success in other policy arenas in addition to some limited evidence of increasing demand for timely vaccination. Assuming that financial incentives are able to significantly boost coverage among the more economically disadvantaged, as was assumed in this paper, this approach could be used to target these households, which have lower levels of vaccination coverage. Another, more hybrid policy approach would be a combination of routine immunization with financial incentives and SIAs. While possibly less efficient, this approach would recognize differences in suitability and impact across different groups, and harness the benefits of both.

5. Conclusions

This paper applied ECEA to evaluate different strategies to improve measles vaccination coverage in Ethiopia. In addition to the standard options of routine immunization services and SIAs, the use of financial incentives was introduced based on evidence from the CCT literature that this type of program increases demand for child health services. ECEA was a particularly appropriate method in this regard, since it intrinsically captured variation in the health and economic benefits of each strategy by income quintile. Ultimately, no one strategy was superior in terms of both health and economic benefits. SIAs and routine immunization with financial incentives required similar levels of investment, with SIAs delivering a more sizable reduction in measles-related deaths and financial incentives bringing about greater economic improvements. These are the types of strategies that are relevant for measles eradication, and the relative attractiveness of these two alternatives will largely depend on characteristics of the funding climate and the degree to which immunization policymaking is conducted in concert with the broader health system strengthening and social agendas.

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