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Supplementary material

# Supplementary File 2: Economic evaluation technical content

## Methods

### Evaluating costs

Costs of the QI capacity development intervention were collected in 2017 using an ingredients costing approach with a health systems perspective. Resource use information was valued in 2017 prices and annualised, with detailed results published in Kumar et al. 2019.(1) We used the economic costs for Kenya presented in this publication, assuming that the costs of a generic QI intervention at community level (as published) are a good representation of the costs of the same community QI intervention where all QI select ANC as their local QI problem. As this is a health system strengthening intervention, the cost is linked to the number of geographic or administrative areas (here, we use sub-county as the intervention unit) rather than the number of pregnant women or patients affected.

### Evaluating effectiveness

We used the following primary health outcomes of interest in the model: maternal death, stillbirth/neonatal death, low birthweight, mother-to-child transmission of HIV, and congenital syphilis. These were selected because they can be influenced by early diagnosis and treatment if the first ANC visit is before 16 weeks (2–5) and by skilled birth attendance,(6,7) both of which have been shown to be improved by community QI in the USAID SQALE[1] study in Migori, Kenya.(8) Secondary (policy) outcomes of interest were: early first ANC visit in first trimester and skilled birth attendance (SBA). DALY weights were obtained from the most recent Global Burden of Disease study.(9) DALYs averted, calculated by DALY weights multiplied by the length of affected life (using average Kenyan life expectancy data) are drawn cumulatively from the morbidity and mortality impacts of early detection and treatment of HIV, anaemia and syphilis in ANC visits and on maternal mortality averted due to increased skilled birth attendance. National scale data on effectiveness are based on estimated 1,361,326 pregnancies in Kenya per year (estimate from 2019 census data and DHS birthrate data)

### Evaluating cost-effectiveness

In assessing the incremental cost-effectiveness DALYs averted, we use the threshold range for Kenya of $32-519 as suggested by Woods et al. as our benchmark.(10) We inflated these from 2013US$ (reported) to 2017US$ to align with primary costing data used,(11) selecting the actual US$ values reported (not purchasing power parity adjusted) because the actual exchange rate was used in the costing study. The inflated values for the threshold range from $38-621 in 2017 prices; we report against the average of this range, US$329.50 in 2017 prices, for the deterministic analysis and report the results of the probabilistic sensitivity analysis against a range of thresholds using a cost-effectiveness acceptability curve.

### Study parameters

The following table of parameters (Table A.1) represents the data that inform the model described in Figure 1. In this Table, we show that each chance node is characterized by a base value or point estimate and a distribution. The hierarchy of selection of values for each parameter was as follows: data from Kenya were included where available (national followed by sub-national); data from countries the East African region were considered second tier; beyond that, sub-Saharan Africa and then global estimates for low- and middle-income countries were preferred over country-specific data

[1] USAID SQALE was a three-year implementation research programme that built on the work of REACHOUT in Kenya, improving on it based on the findings and expanding it to additional counties and sub-counties.

given the influence of context on outcomes. Pre/post-intervention parameters for early ANC presentation and skilled delivery were determined from observation of QI teams in the field.(8) The sources of parameter data are noted in Table A.1.

**Sensitivity analysis**

Probabilistic sensitivity analysis was done for costs and outcomes. We conducted a Monte Carlo simulation of 1000 runs for each decision tree and aggregated outcomes across both. The details of values of selected for each parameter in each run are reported in Supplementary File 3.

We report against a threshold of US$329.50 per DALY averted, derived as described above, and vary all input parameters within the distributions assigned in Table A.1. Distributions for each parameter were selected based on the type of parameters and data available from the literature as per recommendations in Briggs et al.(12) In general, for probabilities we used beta distributions and at chance nodes with more than two outcomes, we used Dirichlet distributions. Where data were limited, triangular distributions were assumed; point estimates were used for disability weights. We used a triangular distribution for the costs, considering the results of the base case scenario from Kumar et al. (2019) the most likely value, and the values for active and passive adoption represented maximum and minimum costs respectively; costs are not a strictly stochastic variable as they were directly observed in that study for this specific intervention. The results of the probabilistic sensitivity analysis are presented on an incremental cost-effectiveness plane in the form of a scatterplot for each outcome of interest, as well as a cost-effectiveness acceptability curve of the percentage of runs that are cost-effective for DALYs averted under the intervention compared to standard of care.

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*Table A.1: Main model parameters*

| Parameter name | Base case value | Base case location | Source for values* | PSA Distribution | PSA Parameters** | Other notes*** |
|---|---|---|---|---|---|---|
| **Costs** | | | | | | |
| Cost of implementing quality improvement for community health in one Kenyan sub-county | $ 29,919.47 | Nairobi and Kitui, Kenya | Kumar et al., 2019 | Triangular | Low $27468.06, most likely $29,919.47, high $33,290.52 | Primary data collected from this intervention in three sub-counties (2017USD); base case used as most likely value and cases of passive/active adoption used for low/high values |
| **Care-seeking behaviour** | | | | | | |
| Likelihood of seeking ANC <16 weeks | 0.442 | Migori, Kenya | USAID SQALE household survey, 2019 | Beta | Mean 0.442, SD 0.024 | These data were collected pre-intervention and after one year in nine community units served by community and sub-county QI teams in Migori County Kenya and compared to matched control units in the same County. |
| Likelihood of seeking ANC <16 weeks (post-intervention) | 0.458 | Migori, Kenya | USAID SQALE household survey, 2019 | Beta | Mean 0.458, SD 0.036 | |
| Likelihood of seeking skilled birth attendance (SBA) | 0.803 | Migori, Kenya | USAID SQALE household survey, 2019 | Beta | Mean 0.803, SD 0.020 | |
| Likelihood of seeking SBA (post-intervention) | 0.921 | Migori, Kenya | USAID SQALE household survey, 2019 | Beta | Mean 0.921, SD 0.015 | |
| **Disease incidence, diagnosis and treatment** | | | | | | |
| Probability of syphilis + | 0.0325 | East Africa | Hussen et al., 2019 | Beta | Mean 0.0325, SD 0.0051 | |

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| Parameter name | Base case value | Base case location | Source for values* | PSA Distribution | PSA Parameters** | Other notes*** |
|---|---|---|---|---|---|---|
| Probability of anaemic moderate or more severe | 0.118 | Kisumu, Kenya | Ouma et al, 2007 | Beta | Mean 0.118, SD 0.005 | Mild anaemia has limited impact on infant health outcomes so was excluded; SD is estimated |
| Probability of HIV+ | 0.012 | Kenya | AIDS Indicator Survey, 2012 (pub. 2014) | Beta | Mean 0.012, SD 0.0041 | National incident cases |
| Probability of receiving syphilis test | 0.9 | Siaya, Kenya | Barsosio, personal communication, 2019 | Beta | Mean 0.9, SD 0.03 | Estimate; Kenya is now procuring dual HIV-syphilis point-of-care tests so availability is high but not as high as HIV |
| Probability of receiving anaemia test | 0.259 | Siaya, Kenya | Young et al., 2018 | Beta | Mean 0.259; SD 0.298 | |
| Probability of receiving HIV test | 0.99 | Siaya, Kenya | Young et al., 2018 | N/A | N/A | Because probability approaches 1, this is not included in the model |
| Probability that syphilis positive receive appropriate treatment | 0.706 | Siaya, Kenya | Young et al., 2018 | Beta | Mean 0.706; SD 0.0188 | |
| Probability that anaemic receive appropriate treatment | 0.9 | Siaya, Kenya | Young et al., 2018 | Beta | Mean 0.9; SD 0.056 | |
| Probability that HIV positive receive ARVs | 0.483 | Siaya, Kenya | Young et al., 2018 | Beta | Mean 0.483, SD 0.0269 | |
| **Outcomes** | | | | | | |
| with maternal HIV | | | | | | |
| Probability of infant death, HIV+ mother (untreated) | 0.04843 | global systematic review | Wedi et al., 2016 | Dirichlet | (4.8; 15.9; 29.3) | |

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Supplementary material

| Parameter name | Base case value | Base case location | Source for values* | PSA Distribution | PSA Parameters** | Other notes*** |
|---|---|---|---|---|---|---|
| Probability of HIV+ infant, HIV+ mother (untreated) | 0.159 | Kenya | Pricilla et al., 2018 | | | |
| Probability of HIV- infant, HIV+ mother (untreated) | 0.79257 | | | | | Remainder of the sub-group that is not dead or HIV+ |
| Probability of infant death, HIV+ mother (early treatment) | 0.029 | Kenya | Kenya DHS, 2014 (pub. 2015) | Dirichlet | (2.9; 2.2; 94.9) | Equal to infant mortality rate in general population |
| Probability of HIV+ infant, HIV+ mother (early treatment) | 0.022 | Kenya | Pricilla et al., 2018 | | | |
| Probability of HIV- infant, HIV+ mother (early treatment) | 0.949 | | | | | Remainder of the sub-group that is not dead or HIV+ |
| Probability of infant death, HIV+ mother (late treatment) | 0.25725 | Average of early and treatment untreated | | Dirichlet | (25.7; 4; 70.3) | Average of early and treatment untreated |
| Probability of HIV+ infant, HIV+ mother (late treatment) | 0.04 | Kenya | Pricilla et al., 2018 | | | |
| Probability of HIV- infant, HIV+ mother (late treatment) | 0.70275 | | | | | Remainder of the sub-group that is not dead or HIV+ |
| Probability of LBW infant, HIV+ mother (untreated) | 0.1296 | global systematic review | Wedi et al., 2016 | Triangular | Low 0.1128, most likely 0.1296, high 0.1488 | |

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| Parameter name | Base case value | Base case location | Source for values* | PSA Distribution | PSA Parameters** | Other notes*** |
|---|---|---|---|---|---|---|
| Probability of LBW in HIV exposed uninfected infants | 0.08 | Kenya | Project Concern International, 2017 | Beta | Mean 0.08, SD 0.01 | Dara et al., 2019 shows difference in mean birthweight between exposed and unexposed but no difference in percentage of that population low birthweight, so we used probability of LBW in healthy mother |
| Probability LBW in HIV infected infant | 0.1296 | | | Triangular | Low 0.1128, most likely 0.1296, high 0.1488 | Assumed equal to probability of LBW infant in HIV+ mother (untreated) |
| With maternal anaemia | | | | | | |
| Probability of infant death, anaemic mother (untreated) | 0.0899 | Tanzania | Marchant et al., 2004 | Dirichlet | (9; 15; 76) | |
| Probability of LBW, anaemic mother (untreated) | 0.15 | Hungary | Banhidy et al., 2011 | | | |
| Probability of healthy baby, anaemic mother (untreated) | 0.760 | | | | | Remainder of the population that are not dead or low birthweight |
| Probability of infant death, anaemic mother (early treatment) | 0.072819 | global systematic review | Haider et al., 2013 | Dirichlet | (7.3; 10.7; 82) | |
| Probability of LBW, anaemic mother (early treatment) | 0.107 | Hungary | Banhidy et al., 2011 | | | |
| Probability of healthy baby, anaemic mother (early treatment) | 0.820 | | | | | Remainder of the population that are not dead or low birthweight |
| Probability of infant death, anaemic mother (late treatment) | 0.0814 | Average of early and untreated | | Dirichlet | (8.1; 12.9; 79) | Average of early and untreated |

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| Parameter name | Base case value | Base case location | Source for values* | PSA Distribution | PSA Parameters** | Other notes*** |
|---|---|---|---|---|---|---|
| Probability of LBW, anaemic mother (late treatment) | 0.1285 | Average of early and untreated | | | | Average of early and untreated |
| Probability of healthy baby, anaemic mother (late treatment) | 0.790 | | | | | Remainder of the population that are not dead or low birthweight |
| with maternal syphilis | | | | | | |
| Probability of infant death, syphilis+ mother (untreated) | 0.256 | sub-Saharan Africa | Gomez et al., 2013 | Dirichlet | (25.6; 15.5; 58.9) | |
| Probability of congenital syphilis, syphilis+ mother (untreated) | 0.155 | sub-Saharan Africa | Gomez et al., 2013 | | | |
| Probability of no congenital syphilis, syphilis+ mother (untreated) | 0.589 | | | | | Remainder of the sub-group that are not dead or have congenital syphilis |
| Probability of infant death, syphilis+ mother (early treatment) | 0.046 | sub-Saharan Africa | Kuznik et al., 2015 | Dirichlet | (4.6; 0.5; 94.9) | |
| Probability of congenital syphilis, syphilis+ mother (early treatment) | 0.005 | sub-Saharan Africa | Kuznik et al., 2015 | | | |
| Probability of no congenital syphilis, syphilis+ mother (early treatment) | 0.949 | | | | | Remainder of the sub-group that are not dead or have congenital syphilis |
| Probability of infant death, syphilis+ mother (late treatment) | 0.151 | Average of early and treatment untreated | | Dirichlet | (15.1; 8; 76.9) | Average of early and untreated |

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Supplementary material

| Parameter name | Base case value | Base case location | Source for values* | PSA Distribution | PSA Parameters** | Other notes*** |
|---|---|---|---|---|---|---|
| Probability of congenital syphilis, syphilis+ mother (late treatment) | 0.080 | Average of early and treatment untreated | | | | Average of early and untreated |
| Probability of no congenital syphilis, syphilis+ mother (late treatment) | 0.769 | | | | | Remainder of the sub-group that are not dead or have congenital syphilis |
| Probability of LBW, syphilis+ mother (untreated) | 0.121 | sub-Saharan Africa | Gomez et al., 2013 | Beta | Mean 0.121, SD 0.0001 | |
| Probability of LBW if infant has congenital syphilis | 0.193 | Global | Korenromp et al., 2019 | Beta | Mean 0.193, SD 0.01 | Number of LBW divided by the clinical cases of congenital syphilis (subtracting stillbirth and early fetal death); SD assumed same as in healthy mothers |
| Probability LBW if infant is not syphilis+ and mother is syphilis+ | 0.08 | Kenya | Project Concern International, 2017 | Beta | Mean 0.08, SD 0.01 | Estimated same as probability of LBW in healthy mothers |
| with healthy mother | | | | | | |
| Probability of infant death, healthy mother | 0.029 | Kenya | Kenya DHS, 2014 (pub. 2015) | Triangular | Low 0.022, most likely 0.029, high 0.037 | |
| Probability of LBW, healthy mother | 0.08 | Kenya | Project Concern International, 2017 | Beta | Mean 0.08, SD 0.01 | Only mean population value given, SD is estimated |
| with LBW baby | | | | | | |
| Neonatal mortality rate (death in month 1) if LBW | 0.041 | Kenya | Kenya DHS, 2014 (pub. 2015) | Point estimate | N/A | Large sample size of the target population from target country |
| Length of duration, LBW disability | 0.0329 | Mozambique | Sicuri et al., 2011 | Uniform | 2 - 21 days | Acute complications usually resolve within three weeks (or result in death) |

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Supplementary material

| Parameter name | Base case value | Base case location | Source for values* | PSA Distribution | PSA Parameters** | Other notes*** |
|---|---|---|---|---|---|---|
| maternal mortality | | | | | | |
| Probability of maternal death, SBA | 0.001 | Kenya, Bangladesh | Kenya DHS, 2014; Fauveau et al. 1991 | | | Uses relative risk of mortality in observational study applied to Kenyan maternal mortality rate; Difference between 0.00326 (Kenyan maternal mortality) and probability of maternal death without SBA under the selected distribution |
| Probability of maternal death, no SBA | 0.0026 | Kenya, Bangladesh | Kenya DHS, 2014; Fauveau et al. 1991 | | | Same as above |
| **Life Expectancy** | | | | | | |
| Life expectancy at birth, healthy | 66.65 | Kenya | WHO life tables | Point estimate | N/A | |
| Life expectancy at birth, LBW | 57.96 | sub-Saharan Africa | Fernandes et al., 2015 | Triangular | Low 52.91, High 64.8 | |
| Life expectancy at birth, HIV+ | 28.8 | Africa | Ciaranello et al., 2015 | Point estimate | N/A | |
| **Disability weights** | | | | | | |
| Maternal death | 1 | Global | | Point estimate | N/A | |
| Neonatal death/stillbirth | 1 | Global | | Point estimate | N/A | |
| Low birthweight | 0.291 | Global | Global Burden of Disease, 2017 (Kyu et al., 2018) | Point estimate | N/A | |
| Congenital syphilis | 0.315 | Global | Global Burden of Disease, 2017 (Kyu et al., 2018) | Point estimate | N/A | |

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| Parameter name | Base case value | Base case location | Source for values* | PSA Distribution | PSA Parameters** | Other notes*** |
|---|---|---|---|---|---|---|
| HIV+ (at birth) | 0.123 | Global | Global Burden of Disease, 2017 (Kyu et al., 2018) | Point estimate | N/A | |

* If more than one reference is given, the final value represents a summary value

**For beta distributions, we have described these using mean and standard deviation for ease of understanding for the non-economist reader. These were converted to alpha and beta parametrization using the following formulae:

$\alpha = (((\mu\text{^}2) * (1-\mu))/((\sigma\text{^}2) - \mu))$

$\beta = \left((1-\mu) * \left((1-\mu) * \mu\right)/(\sigma^2 - 1)\right)$

***For disability weights, the equivalent category in the Global Burden of Disease Study 2017, which was used for the disability weight of each of these health states, is described. Where comorbidity was observed, the deterministic model used the cumulative value of the two health states for the duration of comorbidity and reverted to the disability weight of the single persistent health state for the remaining duration. A uniform distribution ranging from the higher of the two single disability weights to the deterministic cumulative weight was used in the probabilistic sensitivity analysis

References for *Table 1: Main model parameters* (1,8,9,13–31)

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## Results

### Characterising uncertainty

Results of the one-way sensitivity analysis around the two key intervention parameters and the costs are shown in a tornado diagram (Figure A.1 below). This shows highest sensitivity to cost but all ICERS are cost-effective, falling between US$242-267 per DALY.

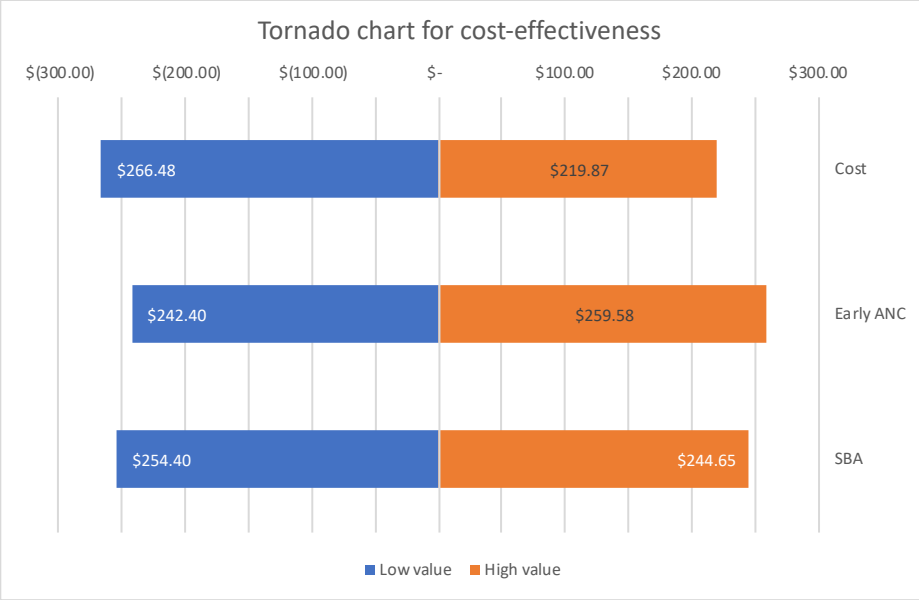


*Figure A.1: Tornado diagram of one-way sensitivity to selected model parameters*

In the probabilistic analysis, we found 76.4% of the 1000 runs more cost-effective than the average of the threshold maximum and minimum values (3.2% of the simulations fell in the northwest quadrant, showing the intervention as more expensive and less effective than standard of care in terms of DALYs averted were cases where the impact was negative; 23.6% of the cases exceeded that average). Under the least strict threshold or high end of the threshold range (US$621), 93% were cost-effective; under the strictest threshold or low end of the range (US$38), none were cost-effective, as shown in cost-effectiveness acceptability curve for incremental cost per DALY averted at the different thresholds in Panel 2 of Figure A.2.

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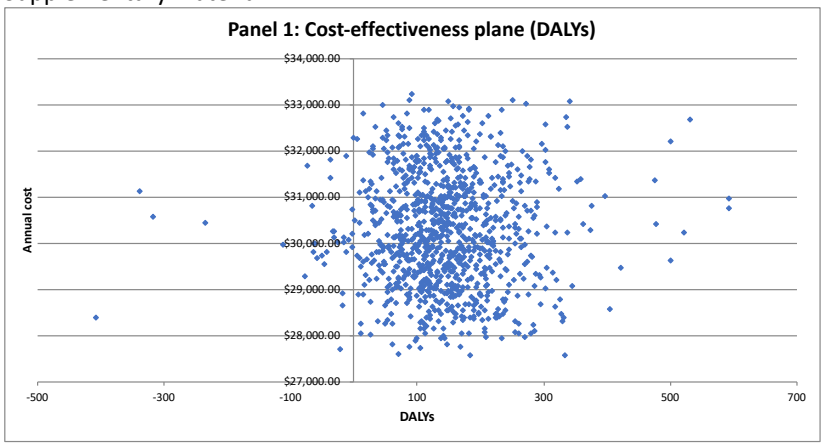


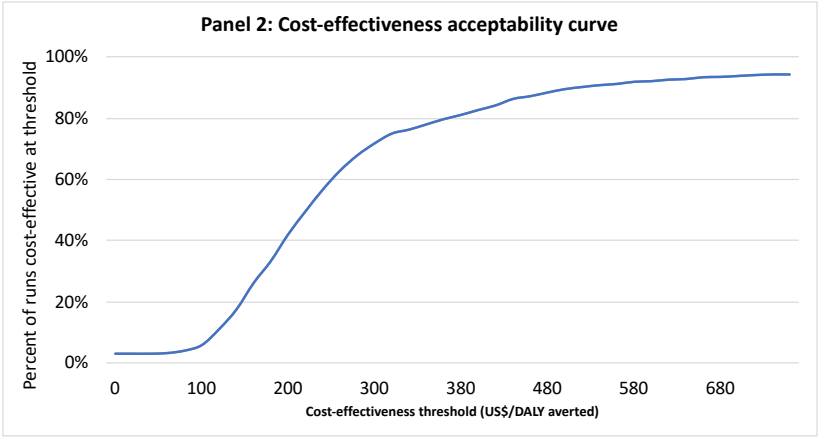


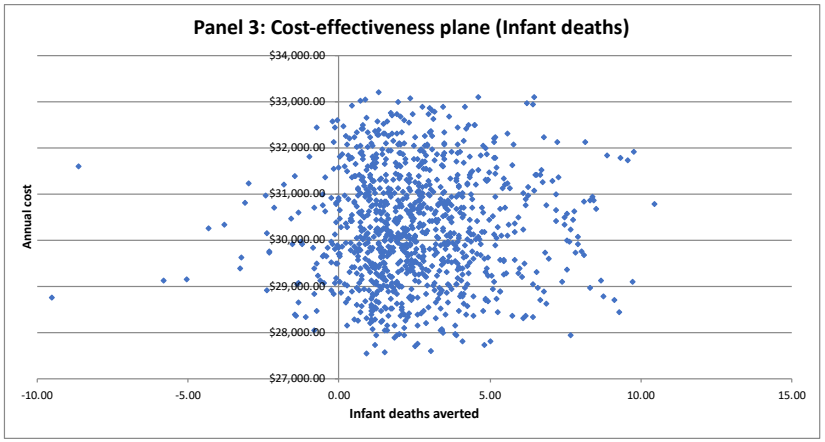


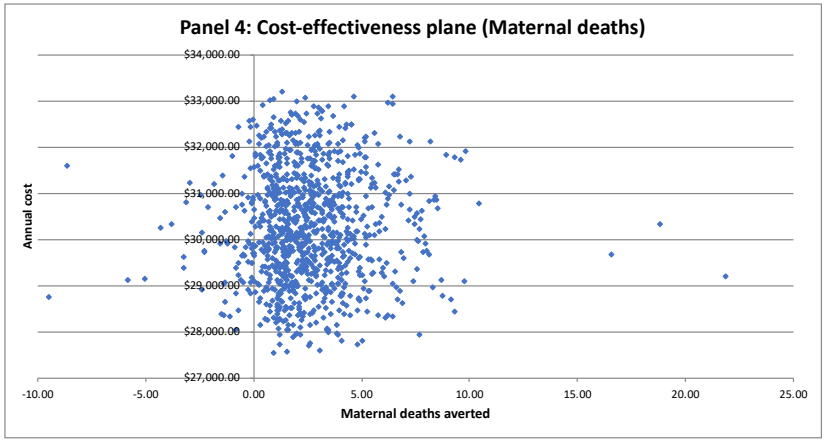

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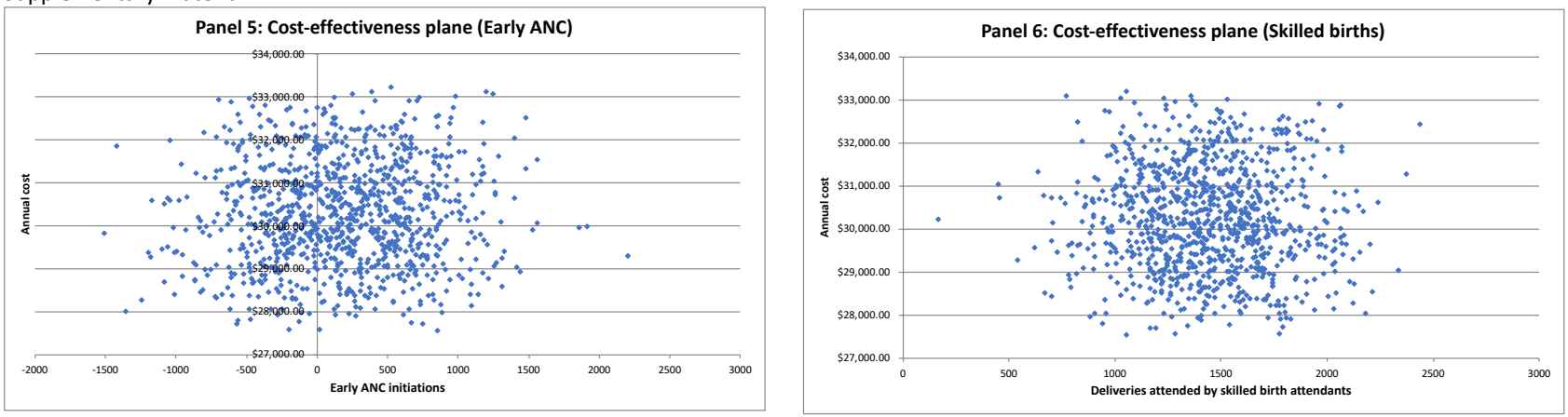


*Figure A.2: Cost-effectiveness planes for outcomes of interest*

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**Goodness of fit of the model: heterogeneity and limitations**

For most of the parameters, we were able to identify either primary or secondary sources from Kenyan or East African populations, raising confidence in the model fit. Some uncertainty related to heterogeneity remains including:

- Variations in implementation of the community strategy in different counties (formation/coverage and functionality of community units; ratio of community health workers to population)
- Regional variation in burden of disease (particularly relevant for malaria, anaemia)
- Equity of access to healthcare (includes distance to facility as well as socioeconomic household characteristics, ethnicity)
- Individual behaviours and care-seeking choices (experiences with the healthcare system, home circumstances, parity, age, education)

However, community health is intended to overcome some barriers to access to healthcare and we have used the recommendations from national policies/approaches where possible. As county governments are the healthcare fund holders in Kenya, a county-level analysis would be recommended to define specific funding requirements and should include more granular detail on policies, disease and population.

In the intervention study, routine indicators tracked by QI teams could be categorized in four areas: child health (growth monitoring, nutrition), maternal health, and data quality/referral.(32) We expect that if a team were to focus on a given indicator as its QI problem, the rate of increase would be greater than what is observed coincidentally in these cases. When we examine the DALYs yielded by the model, 79% of the DALYs are yielded from the maternal tree. The one-way sensitivity analysis shows that there is limited sensitivity to these variables within the extremes of the measured range (Supplementary Material 3). The magnitude of benefits (and even the beneficiaries) obtained by targeting the different routine indicators would vary, and this could in turn influence the assessment of whether the intervention is cost-effective. We would expect that, for example, given the number of children under five is much greater than the number of pregnant women, interventions around nutrition and growth monitoring would be more likely to yield significant benefits (though they require behaviour change by the adult caregiver as well). Interventions around processes (such as referral, reporting and data) are likely to be more challenging to link to health benefits, but may yield significant increases in policy-relevant and -valued outcomes, such as high-quality community-level data.

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