Impact of scaling up modern contraceptive coverage in Ethiopia: Subnational cost effectiveness analysis

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Thesis submitted in partial fulfillment of a master's degree in Global Health, Department of Global Public Health and Primary Care
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June 2020

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Abstract

Background

Ethiopia, a sub-Saharan African country with high maternal and child mortality rates, has a low modern contraceptive prevalence of 35%; this level of utilization meets 60% of the demand among married and in-union women, according to the 2016 Ethiopian Demographic and Health Survey (EDHS). Contraceptive use among married and in-union women globally is 63%, meeting 78% of the demand for this group of women. In addition to the low contraceptive prevalence in Ethiopia, there is a difference among regions, running from 1% to 50%. The country has pledged to increase the national prevalence of modern contraceptive use to 55% (of all married women of fertile age), with a greater focus on long-acting methods, mainly focusing on addressing unmet need for contraceptives. This effort needs a substantial budget increase. The cost-effectiveness of scaling up modern contraceptive coverage may vary among regions, and there are no studies from Ethiopia that document the cost-effectiveness of scaling up contraceptive coverage at the subnational level.

Objective

The objective of the study is to analyze the cost-effectiveness of scaling up modern contraceptive coverage at a subnational level among Ethiopian regions and to estimate the budget needed for each region. This information could be useful for decision makers who aim to maximize the health impact and equalize coverage across regions.

Methodology

The analysis was conducted using a Markov model in which the status quo modern contraceptive coverage level of each region was compared with a scaled-up and equalized modern contraceptive coverage level across all regions. The model was built to simulate the experience of a cohort of 15-year-old reproductive females who are not initially sexually active and who may become sexually active or remain sexually inactive, in relation to modern contraceptive usage status over the time horizon of women's reproductive years. The modeling was based on secondary data. Transition probabilities and healthcare provider–related costs were extracted from the latest EDHS and relevant

published papers. The disability weights were collected from the Global Burden of Disease study. All the costs and benefits were discounted by 3% every year. The primary outcome of this study is cost per quality-adjusted life year (QALY) gained, which is the result of the reduction in unintended pregnancies. The number of averted unintended pregnancies and unwanted clinical events, such as abortion and complicated pregnancy, are secondary outcomes. I also estimated the budget needed to scale up the intervention in all regions. I did deterministic and probabilistic sensitivity analyses to check the impact of the uncertainty of parameter estimates on the cost-effectiveness of the intervention and the robustness of findings in the face of parameter uncertainty. Twelve models were built, 11 for the nine regions and two city administrations and one to be used as a national-level model. Subsequent analysis was conducted separately and compiled for regional comparison. TreeAge Pro version 2020 and Microsoft Excel were used for building the model and analysis.

Research Ethics

As the study used publicly available reports and published studies as data sources, ethical clearance was not necessary.

Results

The intervention, which is scaling up modern contraceptive coverage, dominates the status quo coverage. Scaling up coverage to 55% is cost saving in all regions since the intervention results in more QALYs gained at a lower cost. Scaling up modern contraceptive prevalence to an average of 55% for 15-year-old females in their reproductive age will result in savings of about US$49 million at the national level (range: from US$0.16 million to US$24 million in different regions). The intervention also reduces close to 700 thousand unintended pregnancies. The one-way sensitivity analysis shows that the incremental cost-effectiveness ratio (ICER) is most sensitive to the cost of modern contraceptives and the cost of delivery, especially in Addis Ababa (AA) , Tigray, and the Southern Nations, Nationalities, and Peoples' (SNNP) regions. In the probabilistic sensitivity analysis, there is a 65% probability that the intervention will be a cost saving option and a 78% probability that it is cost-effective.

Discussion

The regions where the status quo coverage is low will see more QALYs gained. The per capita cost saved is large in Somali and Afar regions. This could be because of the low coverage, combined with the large rural proportion of the population. The regions with higher rural population proportions will have higher investment costs to implement the intervention and are the ones that will gain the highest return on the investment. The finding that scaling up contraceptive coverage is cost-effective was found to be similar in other studies conducted in Uganda and Indonesia. One important limitation of this study is that the model has not incorporated non-health benefits and health benefits related to child health of increased modern contraceptive coverage. This may have resulted in underestimation of the cost-effectiveness of the intervention.

Conclusion

The results show that scaling up and equalizing modern contraceptive coverage across regions is not only cost-effective but could also be cost saving. This information may be useful for budget appraisals.

Acknowledgments

First, I would like to thank almighty GOD who have been protecting me throughout my life and who gave me the strength to reach where I am now.

I am indeed very much thankful to my supervisors Professor Ole Frithjof Norheim (Director of BCEPS) and Mieraf Taddesse Tolla. They have made my journey smoother with their intellectual support. They have helped me learn a lot in the field of health economics.

I would also like to thank Stéphane Verguet who helped me acquire good knowledge on the field of health economics during my stay at Harvard T.H. Chan School of Public Health.

Finally, my gratitude goes to My wife Samrawit Tariku, my brother Michael Argaw and the rest of my family who have been reaching out in all their ability during my master’s training.

1. Background

Contraceptive methods comprise any method that helps a reproductive woman to space or limit the number of her pregnancies (1, 2). Depending on the method used, contraceptives can be classified as traditional or modern. Coitus interruptus, vaginal douching after sexual intercourse, and the calendar method are categorized as traditional contraceptive methods. Oral contraceptive pills, condoms, diaphragms, cervical caps, injectables, implants, intrauterine devices (IUDs), and tubal ligation are regarded as modern contraceptive approaches (2). These modern contraceptives are also broadly categorized as short acting, long acting, and permanent, according to the length of the period over which they are capable of preventing pregnancy. Oral contraceptives, the barrier methods, and injectables are short-term modalities, while hormonal implants and IUDs are long-term modalities, and tubal ligations are a permanent modality (3).

Contraception, in addition to the benefit of controlling family size, helps to reduce maternal and child mortality, empowers people, and slows population growth, and some of them help to prevent sexually transmitted infections (1, 4). Oral contraceptives are known to protect against some cancers and pelvic inflammatory disease, and barrier methods have a protective effect against sexually transmitted infections, including HIV (5). A study by Ahmed et al. from 2012 estimated that contraceptive use averted 40% of maternal deaths worldwide by reducing unintended pregnancies (6). The decrease in number of pregnancies by itself reduces maternal death because deaths related to pregnancy are by definition considered maternal deaths. The decline in subsequent fertility in women with high parity while using contraception is another way in which obstetric risk is reduced (6, 7). Increasing the gap between pregnancies by more than 24 months—spacing—is also known to improve perinatal and child survival. This is because of the aversion of the increased risk of preterm birth, low-birth weight, and small size for gestation, which happens when the interpregnancy gap is less than 18 months (7). In low-income countries, another explanation could be that the care can be continued for a child that would otherwise have been minimized or lost because of the birth of another child or because the mother had died, thus helping to reduce child mortality. Rapid population growth (>2%) is a threat to wellbeing in the poorest countries because of its adverse social, economic, and environmental pressures (4, 8), thus increasing the importance of contraceptive use on the policy agenda.

According to the United Nations Department of Economic and Social Affairs' World Family Planning 2017 report, contraceptive use among married and in-union women globally was 63% and above 70% in Europe, Latin America, the Caribbean, and Northern America. The proportion of demand satisfied by modern methods globally is 78%. The proportion of needs met by modern contraceptive is just 56% in Africa, however, while it is more than 75% for other regions (9). As is the case for many other health indicators, the least developed countries have much lower contraceptive coverage than do most of the developed countries. This coverage gets even lower for sub-Saharan Africa, where the prevalence of contraceptive use is 33% among married and in-union women while it is 40% for less developed countries (10). As of 2017, there were 885 million reproductive-age women in developing countries who need contraceptives, of whom 75.8 % are using modern contraceptives, with the remaining 24.2% classified as having unmet need. Of those 214 million women who had unmet need, 27.6% are using traditional contraceptive methods. The proportion of women who have unmet need in sub-Saharan Africa is also more than 20%. Because of this unmet need, 43% of all pregnancies are estimated to be unintended in this developing region of the world (11).

Ethiopia is a low-income sub-Saharan African country with a projected population of more than 110 million in the year 2020. Sixty percent of this population is under 25 years of age. The country has nine regions and two city administrations. Eighty percent of the population resides in the rural part of the country. In 2016, Ethiopia had a modern contraceptive coverage of 35% among married women, up from 6% in the year 2000. However, this coverage varies by region in Ethiopia, ranging from 1% in Somali region to 50% in the capital, Addis Ababa (Figure 1). The figures are lower still for contraceptive use among all women, ranging from 1% in Somali region to 34.1% in Amhara region.

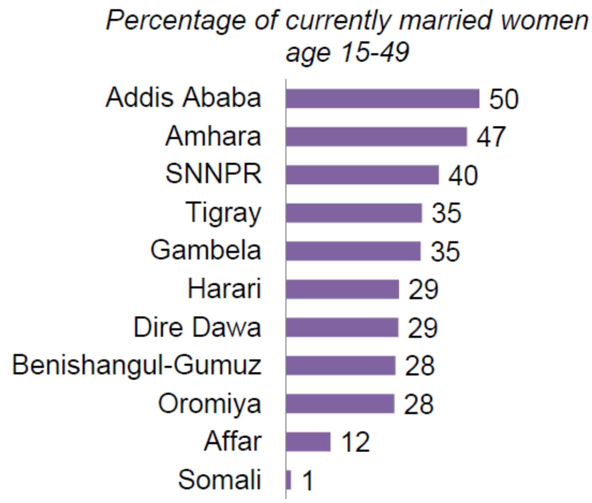


Figure 1. Use of modern contraceptive methods among married women by region, from the 2016 EDHS

Injectables and implants are the two most commonly used modern contraceptive methods in Ethiopia in all regions, while female sterilization is the least common. Eighty-four percent of modern contraception is provided in the public sector. Health centers and private facilities at the same level comprise the largest share of the contraceptive service providers.

Utilization of contraception can be affected by multiple socioeconomic factors. Poor women use contraception much less than wealthier women do, as has been shown by the positive concentration index in a study by Creanga et al. that aimed to assess contraceptive use among poor women in Africa (12). The findings were similar to those for Ethiopia, with coverage of modern contraception varying across the wealth quantiles from 20% in the poorest to 47% in the wealthiest. This inequality among wealth quantiles also shows up in the educational status of women. Coverage is 31% for those who have had no schooling while it is 51% for those who have completed secondary school (13). Contraceptive utilization can also be affected by geographical location of residence. The coverage of modern contraception in Ethiopia in urban and rural parts of the country is 50% and 32%, respectively (13, 14). Distance from service-providing facilities, the availability of contraceptive methods, and availability of health professionals who can provide the service are other determinant factors that affect contraceptive use. Together, these can be described as access to contraceptives in general. The better the access, the better the probability of utilization of contraceptives.

Ethiopia has shown considerable progress on contraception and has been regarded as one of the emerging contraception success stories. This is mainly attributed to generous donor support, non-governmental and public–private partnerships, and the government's establishment of a network of health-extension workers. The innovative health extension program that brought various existing health services close to the community helped to improve maternal-related health indicators (15). However, the total fertility rate (TFR) and population growth in Ethiopia are still at 4.6 and 2.6, respectively, meaning that if the country is to meet its plan to become a middle-income country, the task is still immense. The rights-based contraceptive approach is one strategy to address this challenge (16). The country has pledged to increase contraceptive prevalence among married women from the then status quo coverage to 55% by 2020 and to reduce the TFR to 3 by 2020 (14). Ethiopia needs an estimated US$285 million in the period from 2015 to 2020 to meet these targets (17).

2. Rationale

Although Ethiopia's track record with regard to contraception is good, the target originally set for 2020 is still a long way off. The gap can be addressed by planning for higher coverage among those with an unmet need for contraception and by creating the demand for modern contraception where it is low. The country plans to lower the TFR to 3 by 2020, which is still a high TFR. However, the country cannot plan for a further lowering of the TFR because the budget needed for the already existing target needs health sector budgeting with a family planning focus from both the federal and regional governments. This could be an earmarked budget or an increase in the already existing budget for maternal and child health. In its "Costed Implementation Plan" of 2016, the Ministry of Health noted that it needs evidence-based advice to convince the government to put extra money toward realization of the plan (17). If the budget for modern contraception is to be provided by the federal government to the regions, it will also need to be invested cost-effectively. Cost-effectiveness of scaling up modern contraceptive coverage could vary by region, given the wide differences in coverage, demand, and the costs of scaling up. Despite searching widely for subnational cost-effectiveness analyses, I was unable to find studies documenting the cost-effectiveness of scaling up contraceptive coverage by subgroups characterized by area of living.

This study will produce national and regional incremental cost-effectiveness ratios (ICERs) that can help policymakers to make evidence-informed decisions as to whether scaling up and equalizing modern contraceptive coverage among regions is cost-effective and where among the regions such cost-effectiveness would be better.

3. General and Specific Objectives

a. General objective

Determine the costs and effects of scaling up and equalizing coverage of modern contraceptive methods to reduce unmet need in all regions of Ethiopia by using economic modeling and sub-group analysis.

b. Specific objectives

i. Determine the costs of scaling up modern contraceptive methods for each region in Ethiopia.

ii. Determine the effectiveness of scaling up modern contraceptive methods for each region in Ethiopia.

iii. Estimate the cost-effectiveness of scaling up and equalizing coverage of modern contraceptive methods across regions by Markov modeling analysis.

iv. Estimate the budget needed by each region to implement the new level of coverage.

4. Methodology

4.1. Model overview

This study followed the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement (18)(see Annex 1). A Markov decision analytic model was developed to analyze the costs, effects, and cost-effectiveness of scaling up modern contraceptive coverage compared to the status quo situation for a cohort of 15-year-old females in Ethiopia, using a time horizon of women's reproductive years, making 2016 the baseline year. The proportion of unmet need was defined in line with the definition of the World Health Organization (WHO), namely, the gap between women's reproductive intentions and their actual contraceptive utilization behavior (19).

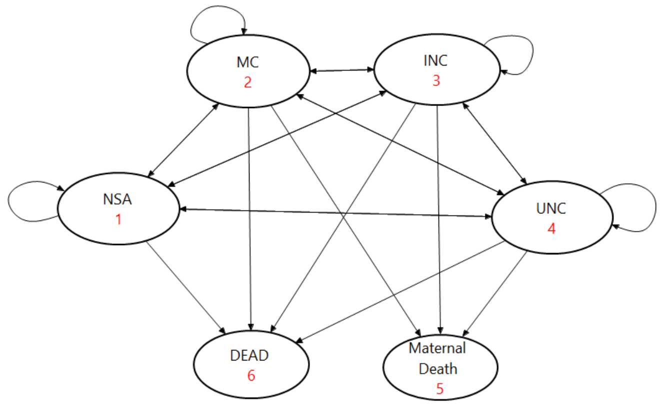
The model simulated the sexual activity and experience of modern contraceptive use of a 15-year-old female in all regions and on a national level. In the analysis, the intervention arm was increasing the contraceptive prevalence rate to 55% coverage, a coverage level that was chosen because it was the initial modern contraceptive coverage target for the "married women" group in the FP2020 plan. The comparator was modern contraceptive coverage among all reproductive-age women in all regions and at the national level for the year 2016 (EDHS). The primary outcome of the study is cost per quality-adjusted life year (QALY) gained, which is the result of a reduction in unintended pregnancies. Clinical outcomes like number of averted unintended pregnancies (and its potential consequence, abortion) and complicated pregnancies are secondary outcomes. The cost of scaling up and equalizing modern contraceptive coverage per region is a third set of results of particular interest.

The study looked at costs from a healthcare-provider perspective. Long-term costs and health outcomes were discounted at 3%, a rate commonly used in many countries (20). I used half the GDP per capita for this study as the willingness to pay threshold. This threshold is different from the WHO CHOICE's recommendation of an ICER below one GDP per capita and above three GDP to define interventions as very cost-effective or not cost-effective, previously used in many cost-effectiveness analyses (21). Recently, such usage has been questioned by researchers. In a study by Woods et al., it was suggested that thresholds vary with countries' income and health care spending (22). In that study, assuming different levels of income elasticity, the cost-effectiveness threshold for low-income, lower-middle-income, upper-middle-income, and higher-income countries ranged from as low as 3% to as high as 129% of GDP per capita (22). For my study, I used 50% of GDP per capita as the threshold because it was at the higher end of the recommended cost-effectiveness threshold for low-income countries.

I did face validation for the model by inserting extreme values and double checking the input data. Deterministic and probabilistic sensitivity analyses were conducted to investigate the impact of model parameter uncertainty on cost-effectiveness results. The model was built using TreeAge Pro software, and this software and Microsoft Excel were used for analysis.

4.2. Model structure

The state transition diagram representing the Markov model is shown in Figure 2. For the analysis, a cohort of 15-year-old females was followed over the time horizon of their reproductive age (35 years). The model had six health states, the first four of which represented different behaviors with regard to sexual activity and modern contraceptive utilization, the remaining two being death states, of which one was pregnancy related and the other was background death from other causes. The Markov model (see Annex 2) was built on the following assumptions: When a sexually inactive 15-year-old reproductive-age female becomes sexually active, she can be in one of the following three states with respect to utilization of contraception: a) starting to use modern contraceptives, b) intentionally not using contraception because she wants to get pregnant, or c) unintentionally not using contraception because of either a lack of access or a lack of individual awareness, categorizing her as a female with unmet need. Sexual activity was defined as sex within the previous year as reported by reproductive-age females, as per the EDHS. For this study, females who were using traditional contraceptive methods were considered to be unintentional non-users of contraceptives.



Explanations:
NSA = Not sexually active
MC = Modern contraceptives
INC = Intentional non-user of contraceptives (those who want to get pregnant)
UNC= Unintentional non-user of contraceptives (unmet need)

Figure 2. State transition diagram describing possible health states of reproductive-age females

A reproductive-age female can become “unintentionally pregnant” either because she was not using contraception unintentionally or because of modern contraceptive method failure. Those who intentionally did not use contraceptives could also become pregnant, defined as intentional pregnancy. Induced abortion was assumed to be zero in this group because the pregnancy was an intended one. However, induced abortion will be present in those with unintentional pregnancies.

The age-specific proportions of reproductive-age women in all regions and at the national level, who were sexually active, who were using modern contraceptive methods, and who had an unmet need for modern contraceptives are provided in Tables 3–5. All women who were sexually active had a chance of becoming pregnant. The probability of becoming pregnant, which was adjusted for menopause with aging as per the information found in the EDHS, was assumed to be identical for both intentional and unintentional non-users of modern contraceptives, representing the probabilities of becoming pregnant without any contraceptive methods (Table 2) (23). The probability of becoming pregnant while on modern contraception was considered to be similar to the probability of modern contraceptive method failure. In the absence of specific data, the probability of transitioning from the unintentional non-user of contraception state to the intentional user of contraception state was assumed to be equal to that of transitioning from the sexually inactive state to the intentional contraceptive user health state. Women in the modern contraception state can remain in the same state, discontinue using modern contraceptives intentionally or unintentionally, get pregnant because of method failure, or die from background causes. These probabilities were assumed to be similar in all regions. A pregnant woman will transition to all four alive health states unless maternal death happens. Thus, a mother will jump to the four health states with a probability specific for her age. The probability of becoming sexually inactive after delivery will be similar to the probability of being sexually inactive at that specific age, and this holds true for the other transitions to the other alive health states too. Women in all health states other than the death states can transition to the death state because of background causes of mortality. The probabilities of death for each age group in Ethiopia were collected from the WHO life table (for 2016) for each age group, and this was used for all regions without any variation or adjustment because there are no regional lifetables available (Table 2) (24). Background mortality was calculated by subtracting pregnancy-related deaths from overall mortality in the WHO life table. The probability of pregnancy-related death was taken from the EDHS. The cycle length for this model was one year because it adequately represents the relevant transitions between all health states. Tables 1–5 summarize the input parameters of the model.

4.3. Data sources

Transition Probabilities

State-transition probabilities were extracted from the EDHS and published studies (see Table 1). The probability of becoming sexually active was taken from the number of women who were sexually active within the one-year period of the study. This probability ranged from 20.8% in the 15–20 age group to 85% for the 30–35 age group. It also ranged from 44.4% in Addis to 71.3% in Afar. However, the age-specific probability of sexual activity has not been provided for the regions in the EDHS. Thus, I assumed that the proportion of each age group for the regions would be the same as for the national level and determined the common factors for each age-specific group using the national average and the age-specific probabilities. Then, I either increased or decreased the common factor depending on the way the regional average varied in relation to the national average.

After becoming sexually active. a reproductive-age woman may start to use modern contraceptive methods, a probability that is again dependent on specific age group (Tables 2 and 4). Among those who do not start using modern contraceptive methods, those who unintentionally failed to do so were considered to have an unmet need and the remainder were regarded as having failed to do so because they wanted to get pregnant. The probability of unmet need was also taken from the EDHS. The same calculation method was applied to find the age-specific probabilities in regions as that applied for the probability of becoming sexually active. Those who start modern contraceptive use have a 29.5% probability of discontinuing, of which 57% do so intentionally. The probability of getting pregnant within a year, both for intentional and unintentional non-users of contraception, was 85% (23). This probability of getting pregnant was adjusted for menopause and reached as low as 49% in the final five years of reproductive age (Table 2). The probability of method failure was 2.2%, and this was considered to be the probability of getting pregnant while using modern contraception. Pregnancies that happen while on modern contraception and while not using modern contraception unintentionally were treated as unintended pregnancies. The probability of inducing abortion due to unintended pregnancy was 13% (25), with the remaining pregnancies continuing. There is a 15% chance of pregnancies being delivered after complications while a few mothers died from pregnancy-related complications (26); the remaining mothers deliver safely. Intended pregnancies will have the same probability of complications as the unintended ones, but there will be no induced abortions.

Table 1. Input parameters for Markov model

Parameter	Base case	Sensitivity range	Distribution	Ref.
Probabilities				
Probability of death from induced abortion	0.002	0.0015–0.0025	Beta	(26)
Probability of discontinuing use of modern contraceptives	0.295	0.2213–0.3688	Beta	(13)
Probability of discontinuing use of modern contraceptives unintentionally	0.432	0.426–0.71	Beta	(13)
Probability of inducing abortion for unintended pregnancy	0.13	0.0975–0.1625	Beta	(25)

Probability of modern contraceptive failure and getting pregnant	0.022	0.0165–0.0275	Beta	(13)
Probability of a pregnancy complication	0.15	0.1125–0.1875	Beta	(26)
Discount rate	0.03	0.01–0.05	NA	
Cost				
Cost of abortion service	$58	$29–87	Gamma	
Cost of managing complicated pregnancy	$114	$57–170	Gamma	(26)
Cost of modern contraceptives[a]	$33	$17– 50	Gamma	(27)
Cost of safe pregnancy and delivery	$58	$29–87	Gamma	(27)
Cost of demand generation for modern contraceptives	$3.512	$1.76–5.27	Gamma	(28)
Utilities				
The utility of survival and safe delivery	1	NA	NA	(29)
The utility value for abortion	0.9	NA	NA	(29)
The utility value for complicated pregnancy	0.824	NA	NA	(29)
Utility value for death	0	NA	NA	(29)

[a] This cost varies by region with respect to the urban/rural composition of the population.

Table 2. Age group–based transition probabilities of variables that did not vary across regions

Age	Probabilities of			
	Modern contraception scaled up	Pregnancy adjusted to menopause	Background death	Pregnancy-related death
15–19	0.1640	0.8500	0.0013	0.0003
20–24	0.5762	0.8500	0.0014	0.0006
25–29	0.7734	0.8500	0.0017	0.0007
30–34	0.7668	0.7965	0.0022	0.0010
35–39	0.6449	0.7574	0.0035	0.0011
40–44	0.6139	0.6715	0.0043	0.0011
45–49	0.3634	0.4930	0.0052	0.0008

Health Outcomes

The utility values and disability weights were all extracted from the Global Burden of Disease (GBD) study for 2015 (29). For the model, I chose to estimate outcomes in QALYs. To find the weight of quality of life, I used the disability weights that I found in the GBD table for each specific disease and subtracted it from 1. The quality of life value for death was 0, and for safe delivery a quality of life value of 1 was given. The quality of life weight for complicated pregnancy was found by a weighted average computation method. I extracted data about the prevalence of complicated pregnancy and the proportion of each type of pregnancy-related complication in total complicated pregnancies in Ethiopia from the Ethiopian emergency obstetric and newborn care report of 2016 (26). I then looked for the respective disability weight for these pregnancy complications. The computed weighted average was then taken as the disability weight of complicated pregnancy, from which the QALY associated with complicated pregnancy was found.

Costs

All costs are based on secondary data sources. Costs were considered only for modern contraceptive and pregnancy-related outcomes. I assumed that the other health states were not associated with any costs. Cost data for modern contraceptives was extracted from a costing study of publicly funded primary care facilities, departments, and exempted services in Ethiopia by Berman et al. (27). The cost of modern contraceptives included direct medical costs for intentional modern contraception, which is composed of the costs of the drug and supply, human resources, and the cost of providing modern contraception for one year. Other costs were the costs needed for offices, electricity, running water, etc., to deliver the services (27).

The cost value provided in Berman et al. is a national-level figure and I wanted to estimate how this cost would vary by region, especially depending on the urban/rural composition of the regions. I could not find relevant Ethiopian data on regional variation in costs. A study conducted in Kenya looked at contextual variation in the costs of a community health strategy while being implemented in rural, peri-urban, and nomadic areas. It showed that implementing a community health strategy program in rural and nomadic areas cost 7.2 and 6.4 times more, respectively, than in the peri-urban area (28). I used this ratio to vary the cost of modern contraceptives among regions by applying the same ratio of costs on the human resource portion of the costs by using the urban/rural or urban/nomadic composition of each region in Ethiopia. Information on the national and regional urban/rural composition was extracted from a population projection provided by the Ethiopian Central Statistics Agency (30). I treated the cost of modern contraception extracted from the Berman et al. study as national, and I used the national urban/rural composition to determine the urban cost of modern contraception, which I then used to calculate the costs in other regions.

I also wanted to include the cost of demand generation. Studies about the cost of demand generation per unit increment in the coverage of modern contraception was not available. The cost for demand generation in my study was therefore taken from the above study, in which the cost of implementing a community health strategy was identified and the per capita annual cost for its implementation was treated as the per capita cost needed for demand generation; the same urban/rural or urban/nomadic composition was also used for this one (28). The cost of pregnancy includes the cost needed for four antenatal care follow-ups and for delivery. The assumption in this study is that a mother who delivers will have attended all four antenatal care visits (27). All the services were assumed to be delivered at health-center level because the majority of the family planning, antenatal care, and delivery services take place at the health-center level, as per the EDHS 2016. The cost of complicated pregnancy was taken from the Emergency Maternal Obstetric and Neonatal Care assessment study conducted in 2016 (26). Because of the absence of recent and trusted cost data for abortions, I assumed its cost to be similar to the cost of delivery. All costs were adjusted for inflation and then converted to 2016 US dollars (US$) using official exchange rates and with the World Bank annual consumer price index (31).

The budget impact of both the status quo coverage and the intervention coverage in all regions and at national level was computed by using the number of 15-year-old females in each population. I used the single-age population projection data for the year 2016 that the Ethiopian Ministry of Health collected from the Ethiopian Central Statistics Agency. The agency prepared this single-age population projection on the basis of the 2007 census and demographic health surveys that had been conducted prior to the projection. The five-year-based population projections from 2007 to 2037 are available online from the official website of the agency (30). The total cost needed for both the status quo level and the intervention coverage will then be the product of the size of the 15-year-old female population and the total costs needed for a single 15-year-old female over her reproductive years. The difference between the costs for the intervention and the status quo level will give the incremental cost.

4.4. Sensitivity analysis

I did both deterministic and probabilistic sensitivity analyses to identify which of the parameters could substantially influence the outcomes and to assess the uncertainty of the model's parameters. In the deterministic analysis, I conducted a one-way sensitivity analysis, the results of which are presented as a tornado diagram, with several relevant parameters in the model varied in ranges of plausible values. As most of the parameters used did not have available 95% confidence intervals, I used plus/minus 25% for transition probabilities and plus/minus 50% for costs to provide a range for the sensitivity analysis (Table 1)(32). When the willingness-to-pay (WTP) threshold line is crossed by the tornado in a tornado diagram, it shows that the intervention will not be cost-effective for the value of that specific variable beyond the threshold. Thus, a variable that crosses the WTP is specifically seen in detail to determine the value beyond which the intervention would be not cost-effective. In the probabilistic sensitivity analysis, beta distribution was used for the transition probabilities and gamma distribution was used for cost variables, using the above-mentioned approach to include the standard errors. All parameters were varied simultaneously within their respective probability distributions. A Monte Carlo simulation was used to create 10,000 iterations for which the expected outcomes were calculated.

Table 3. Age group–based probability of becoming sexually active for all regions and national level (p_SA)

Age	Tigray	Afar	Amhara	Oromia	Somali	B. Gumuz	SNNP	Gambela	Harari	AA	DD	National
15–19	0.20	0.23	0.22	0.22	0.22	0.22	0.20	0.20	0.20	0.14	0.18	0.21
20–24	0.62	0.71	0.68	0.69	0.67	0.71	0.64	0.64	0.63	0.44	0.58	0.65
25–29	0.79	0.90	0.87	0.87	0.85	0.90	0.81	0.81	0.81	0.56	0.74	0.83
30–34	0.81	0.93	0.89	0.90	0.87	0.92	0.83	0.83	0.82	0.58	0.75	0.85
35–39	0.78	0.90	0.86	0.87	0.84	0.89	0.81	0.81	0.80	0.56	0.73	0.83
40–44	0.75	0.86	0.83	0.83	0.81	0.85	0.77	0.77	0.77	0.54	0.70	0.79
45–49	0.68	0.79	0.75	0.76	0.74	0.78	0.70	0.70	0.70	0.49	0.64	0.72

B. Gumuz Benishangul Gumuz, SNNP – South Nations, nationalities and population, AA – Addis Ababa, DD – Dire Dawa

Table 4. Age group–based probability of starting use of modern contraceptives (p_MC)

Age	Tigray	Afar	Amhara	Oromia	Somali	B. Gumuz	SNNP	Gambela	Harari	AA	DD	National
15–19	0.04	0.02	0.06	0.04	0.00	0.04	0.05	0.05	0.04	0.04	0.03	0.04
20–24	0.15	0.06	0.21	0.13	0.01	0.14	0.17	0.17	0.13	0.15	0.12	0.16
25–29	0.21	0.08	0.28	0.18	0.01	0.18	0.22	0.22	0.17	0.20	0.16	0.21
30–34	0.20	0.08	0.28	0.17	0.01	0.18	0.22	0.22	0.17	0.19	0.16	0.21
35–39	0.17	0.07	0.24	0.15	0.01	0.15	0.19	0.19	0.14	0.16	0.13	0.17
40–44	0.16	0.07	0.23	0.14	0.01	0.15	0.18	0.18	0.13	0.16	0.13	0.17
45–49	0.10	0.04	0.13	0.08	0.00	0.09	0.10	0.11	0.08	0.09	0.07	0.10

B. Gumuz Benishangul Gumuz, SNNP – South Nations, nationalities and population, AA – Addis Ababa, DD – Dire Dawa

Table 5. Age group–based probability of not starting use of modern contraceptive due to unmet need (p_UNC)

Age	Tigray	Afar	Amhara	Oromia	Somali	B. Gumuz	SNNP	Gambela	Harari	AA	DD	National
15–19	0.02	0.02	0.02	0.04	0.02	0.03	0.03	0.03	0.03	0.01	0.02	0.03
20–24	0.06	0.06	0.06	0.10	0.04	0.08	0.07	0.08	0.07	0.04	0.06	0.07
25–29	0.08	0.09	0.09	0.15	0.06	0.11	0.10	0.12	0.10	0.05	0.09	0.11
30–34	0.10	0.11	0.11	0.19	0.08	0.14	0.12	0.14	0.12	0.07	0.11	0.13
35–39	0.11	0.12	0.11	0.19	0.08	0.14	0.13	0.15	0.13	0.07	0.11	0.14
40–44	0.09	0.10	0.10	0.17	0.07	0.12	0.11	0.13	0.11	0.06	0.10	0.12
45–49	0.06	0.07	0.07	0.12	0.05	0.09	0.08	0.09	0.08	0.04	0.07	0.08

B. Gumuz Benishangul Gumuz, SNNP – South Nations, nationalities and population, AA – Addis Ababa, DD – Dire Dawa

5. Results

5.1. Base-case analysis

The intervention of scaling up modern contraceptive coverage to 55% dominates the status quo coverage because it has lower costs and higher QALYs at the national level (Figure 3). This also holds true for all regions; the intervention is cost saving in all regions, as shown in Table 6. Nationally, for a single 15-year-old female, it would cost $672 in total to meet the intervention coverage during her reproductive years, while the total cost of status quo coverage is $718. The total cost of providing modern contraceptives for the reproductive life of a 15-year-old female with the scaled-up coverage is highest in Oromia ($687) and lowest in Addis Ababa, the capital ($513). The total costs for both the intervention and the status quo coverage vary by region. This difference in cost drops when the intervention is implemented, however. The range and the standard deviation among the regions in the status quo level of coverage are $246 and $64, respectively, while in the intervention they are $174 and $49. The same holds true with regard to effectiveness; the range and standard deviation among the regions in the status quo level is 0.22 and 0.1 QALY while it is close to zero on the intervention side because the total QALY gained over the whole cycle is almost the same in all the regions.

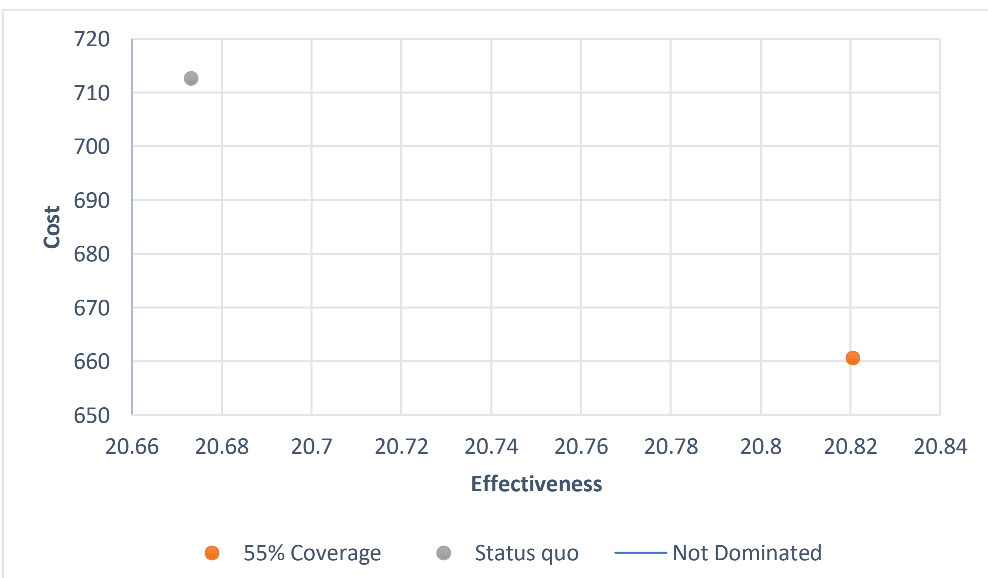


Figure 3. Baseline cost-effectiveness analysis graph of the national model

Table 6. Base-case analysis of incremental cost, incremental effectiveness, and ICER for all regions

Region	Cost			Effectiveness			ICER
	Status quo	Intervention	Incremental	Status quo	Intervention	Incremental	
B. Gumuz	752.2	680.6	-71.6	20.63	20.80	0.17	-425.0
Afar	780.3	685.7	-94.6	20.57	20.80	0.23	-418.7
Harari	697.6	633.4	-64.2	20.66	20.81	0.15	-411.9
Gambela	696.9	646.9	-50.0	20.68	20.81	0.13	-370.9
Amhara	730.9	686.2	-44.7	20.68	20.80	0.12	-368.8
DD	656.5	606.1	-50.4	20.68	20.82	0.14	-350.6
Oromia	745.0	687.3	-57.7	20.64	20.80	0.16	-342.9
Somali	760.6	674.8	-85.8	20.55	20.81	0.26	-337.9
SNNP	710.0	670.7	-39.3	20.68	20.81	0.13	-290.4
Tigray	694.4	654.7	-39.7	20.68	20.82	0.14	-290.1
AA	533.9	513.4	-20.5	20.77	20.86	0.09	-222.9
National	718.4	672.0	-46.4	20.67	20.81	0.14	-321.8

The QALYs gained from the intervention's impact due to the reduction in unwanted pregnancies and related outcomes range from 0.1 QALY in Addis Ababa to 0.26 QALY in Somali region (Table 6). When the intervention is implemented, approximately 0.75 million unintended pregnancies will be averted nationally over the reproductive life of the 15-year-old females who started the cohort (Table 7). This total comprises regional figures ranging from 1,622 in Harari region to approximately 500,000 in Oromia. There will also be 97,000 averted induced abortions nationally, ranging from 211 in Harari to 63,000 in Oromia. The number of averted complicated pregnancies ranges from 2,500 in Harari to 440,000 in Oromia. Close to a million complicated pregnancies will also be averted nationally. In Somali region, there will be 83,000 fewer complicated pregnancies because of the intervention. In addition, a total of 5,880 maternal deaths will be averted. These reductions in unwanted pregnancy–related outcomes will occur in all regions, as shown in Table 7. The regions with higher population numbers will see the greatest reduction in unintended pregnancies and induced abortions. However, averted unintended pregnancies and averted induced abortions in Somali region are unusual in that they will see a lower reduction than some of the regions with higher populations. Percentage wise, there will be at least a 30% reduction in unwanted pregnancies and induced abortions in all regions except Somali and Addis Ababa region, where this figure is approximately

10% (Figure 4). There will also be at least a 40% reduction in complicated pregnancies and maternal deaths in all regions (Figure 5).

Table 7. Number of averted clinical outcomes by intervention in each region and at national level

Region	Averted unintended pregnancies	Averted induced abortions	Averted complicated pregnancies	Averted maternal deaths
Harari	1,622	211	2,525	15
Gambela	3,283	427	3,826	23
Dire Dawa	2,290	298	4,519	27
Ben. Gumuz	9,823	1,277	12,817	77
Afar	11,244	1,462	23,733	142
Addis Ababa	3,255	423	16,279	97
Somali	5,736	746	82,578	491
Tigray	29,073	3,779	53,653	321
Amhara	125,005	16,251	177,818	1,064
SNNP	146,696	19,070	203,154	1,222
Oromia	489,505	63,636	439,059	2,683
National	746,970	97,106	975,886	5,880

SNNP – southern nation nationalities and peoples'

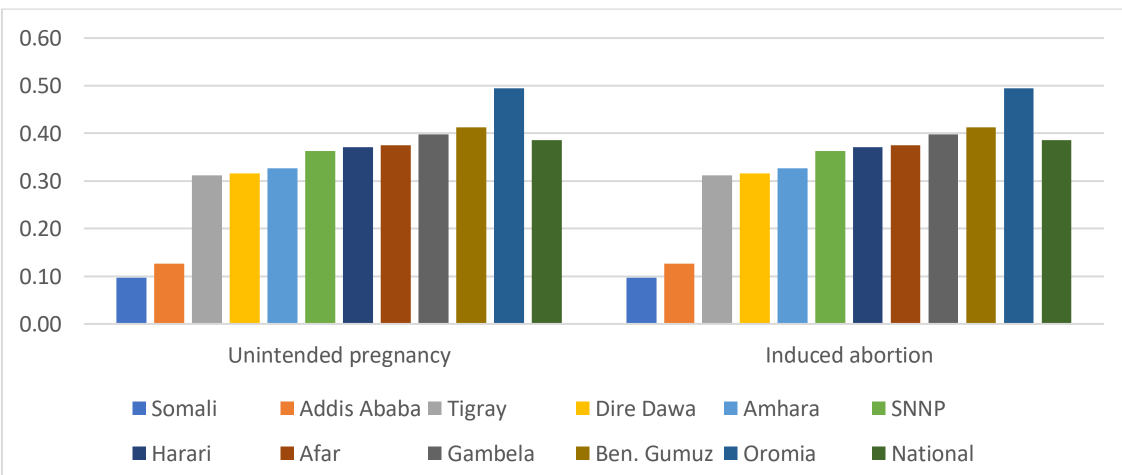


Figure 4. Percentage reduction in unintended pregnancies and induced abortions when the intervention is implemented

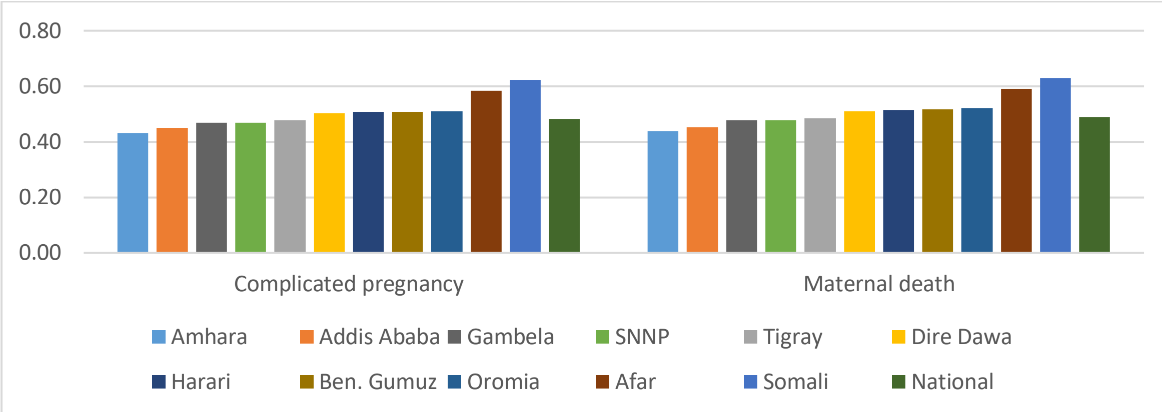


Figure 5. Percentage reduction in complicated pregnancies and maternal deaths when the intervention is implemented

Budget impact

The estimated budget needed to implement the intervention for 15-year-old reproductive-age females over their reproductive life at the national level is US$710 million. This is the budget needed to implement the strategy for the starting cohort of 1.06 million 15-year-old females over their reproductive life (that is, until they reach 49). This cost ranges from as low as US$1.6 million in Harari to US$290 million in Oromia, the regions with the smallest and largest numbers of 15-year-old females, respectively. The costs needed for the implementation of the intervention in each region are presented in Table 8.

Table 8. Budget impact. Total 35-year cost, average per-one-year cost of implementing the intervention, and total and per capita costs saved for cohort of 15-year-old females in all regions in Ethiopia

Regions	Total costs*	Costs/year*	Costs saved*	Per capita costs saved
Harari	1,578,000	45,000	160,000	64
Dire Dawa	2,824,000	81,000	235,000	50
Gambela	2,864,000	82,000	221,000	50
Benishangul	8,252,000	236,000	868,000	71
Afar	11,301,000	323,000	1,559,000	95
Addis Ababa	11,946,000	341,000	477,000	21
Somali	33,060,000	945,000	4,204,000	86
Tigray	38,961,000	1,113,000	2,363,000	40
SNNP	155,773,000	4,451,000	9,128,000	39
Amhara	158,355,000	4,524,000	10,315,000	45
Oromia	290,026,000	8,286,000	24,348,000	58
National	710,277,000	20,294,000	49,043,000	46

* To the nearest thousand. All figures in US dollars.

According to the baseline analysis, the intervention is cost saving in all regions and at the national level, as shown in Table 8. Using the population projection data I have for the number of 15-year-old females in each region for the year 2016, scaling up modern contraceptive prevalence to 55% throughout their reproductive life will result in savings of about US$49 million at the national level. The amount of money saved ranges from as little as US$160,000 in Harari to as much as US$24.3 million in Oromia. However, as shown in the same table, the per capita cost saved ranges from as little as US$20 in Addis Ababa to as much as US$95 in Afar.

5.2. Sensitivity analysis

The univariate sensitivity analysis shown in Figure 6 reveals that the ICER value is most sensitive to the variables cost of modern contraceptives and cost of delivery. Given a WTP level of US$380, none of the variation in the given variables will make the intervention a cost-ineffective alternative in the national model. However, for some regions, the cost of modern contraception and cost of safe pregnancy and delivery will cross the WTP threshold (Figures 7–8). The intervention will not be cost effective in Addis Ababa and SNNP if the cost of modern contraception is above US$39 and US$50, respectively, because the ICER value will be above the WTP if the costs go beyond those amounts (Figures 7 and 8). The one-way sensitivity analysis performed on the national model with regard to the impact of variation of cost of modern contraception on the cost-effectiveness of the intervention shows that it is cost-effective throughout the range of the variation used for the cost of modern contraception, as shown in Figure 9.

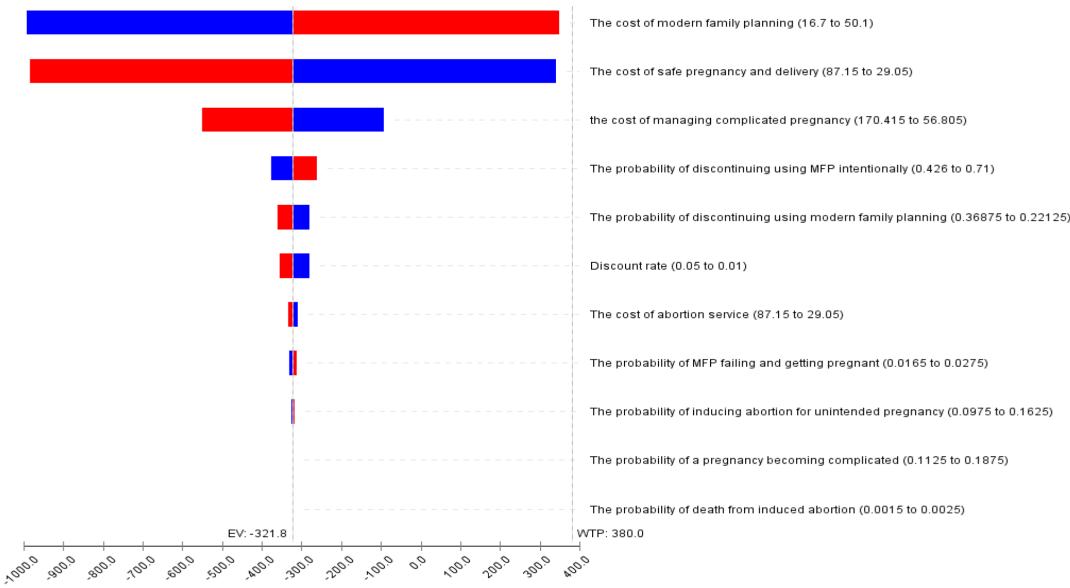


Figure 6. Tornado diagram of the national model

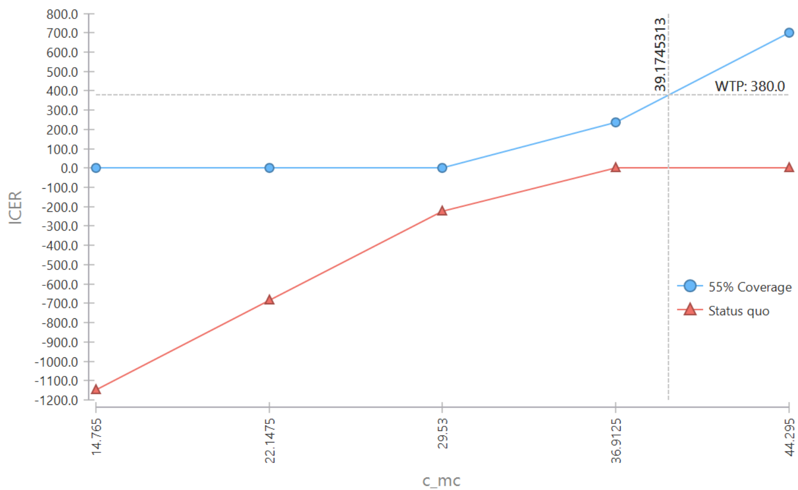


Figure 7. One-way sensitivity analysis of the cost of modern contraceptives vs. ICER for Addis Ababa

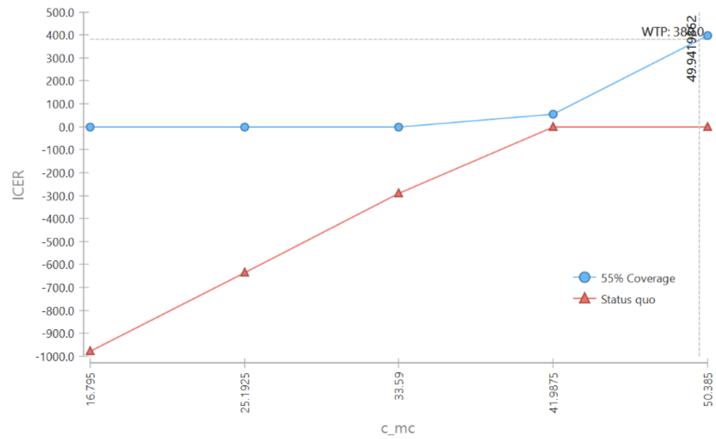


Figure 8. One-way sensitivity analysis of the cost of modern contraceptives vs. ICER for SNNP

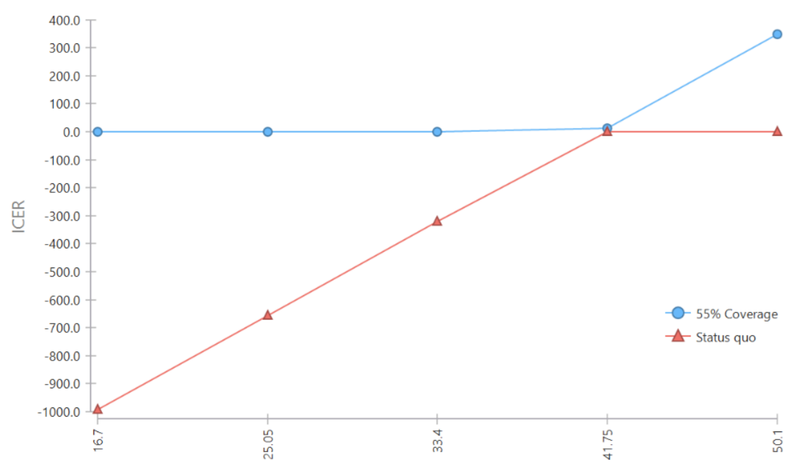


Figure 9. One-way sensitivity analysis of cost of modern contraceptives vs. ICER for the national model

The results from the probabilistic sensitivity analysis (Monte Carlo simulations with 10,000 iterations) show that there is a 65% probability that the intervention will be a cost-saving option, while it is cost-effective 78% of the time (Figure 10). However, there is a 22% probability that the intervention will not be cost-effective since the ICER value will pass the WTP threshold of $380 per QALY even though it results in a better QALY gain. The intervention has a 65% probability of being cost-effective even when the WTP is zero, and this probability that the intervention will be cost-effective increases as the WTP is increased, as shown in Figure 11, and could reach as high as 90% if the WTP is increased to US$800 per QALY. This result is the same if not better in all regions. The sensitivity analysis results for the regions are presented in Annex 3.

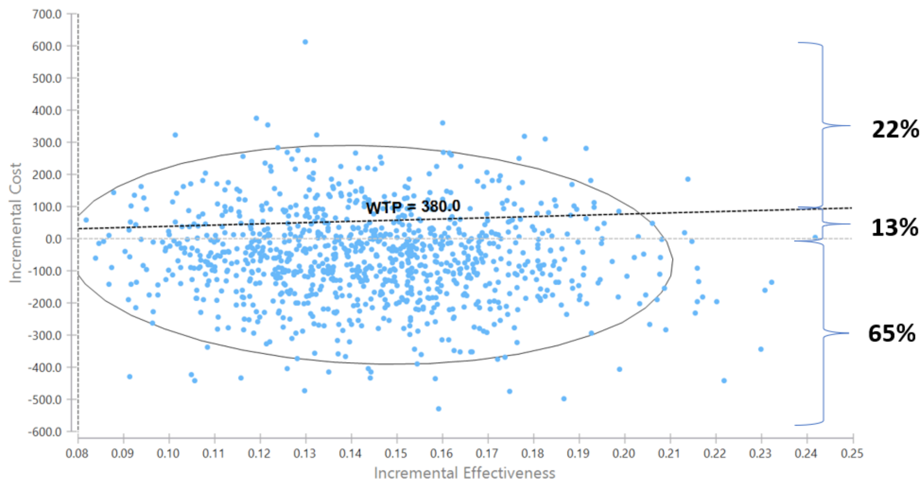


Figure 10. Incremental cost-effectiveness, intervention vs. status quo level, from probabilistic sensitivity analysis of the national model

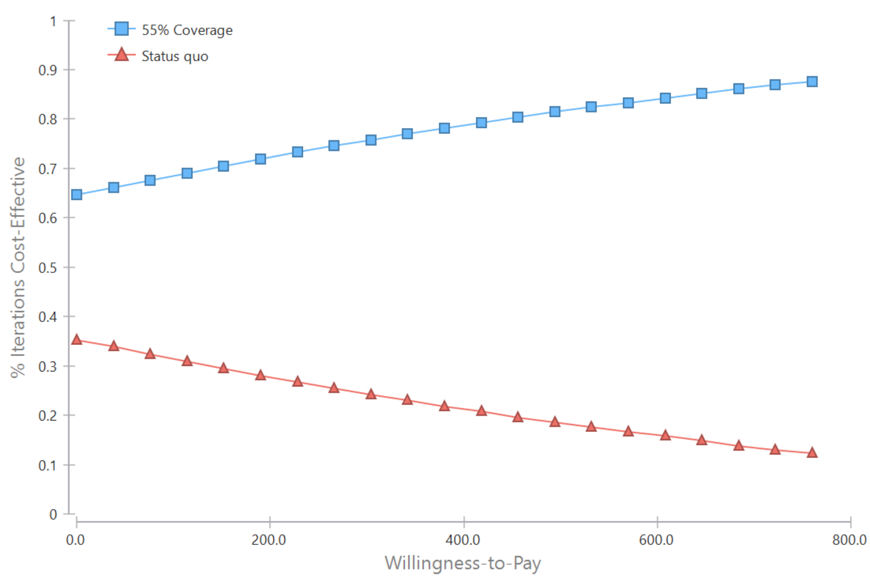


Figure 11. Cost-effectiveness acceptability curve of the national model

6. Discussion

On the basis of the results from the baseline analysis of the model, scaling up the coverage of modern contraception in Ethiopia is cost saving in all regions, dominating the status quo coverage level. This result was robust in the probabilistic sensitivity analysis for the national model and as well for all regions. The QALY gained in the regions was highest in Somali. This could be explained by the fact that the status quo modern contraceptive coverage level is lowest in Somali, meaning that the region benefits comparatively better when the modern contraceptive coverage is increased to a 55% across all regions. A higher QALY gain also appears in other regions with lower status quo modern contraceptive coverage levels.

The analysis shows that larger regions with a larger proportion of rural inhabitants have higher costs than do regions with a large proportion of urban inhabitants. This is because the cost of modern contraceptives is higher in regions with a proportionately larger rural population.

Although we cannot immediately state where in the regions the intervention is most cost-effective using the ICER values that are negative, we can comment on where the intervention can be implemented for better cost saving and where a better incremental QALY can be generated. The intervention has narrowed the difference among the total per capita costs needed for the intervention among the regions, as shown by the decrease in the range and standard deviation of costs. This may likely be because of equalization of the modern contraceptive coverage level, which varies in the status quo. The remaining variations in regional total per capita costs for the intervention after equalization of coverage are most probably due to regional differences in the cost of services. Somali and Afar are regions where the status quo coverage is low, and this, combined with the large proportion of rural inhabitants, seems to have contributed to the comparatively higher per capita costs saved.

When it comes to total health benefits, Somali and Afar are the two regions where more QALYs are generated, which may also be attributed to their lower status quo coverage. However, looking into the clinical outcomes, Somali region has the lowest percentage reduction in unintended pregnancies and induced abortions. This is because, although Somali region has very low modern contraceptive coverage, the unmet need in this region is also lower than the other regions. One may say that the problem in this region is lack of demand rather than simply low modern contraceptive coverage. Thus, the reduction in unintended pregnancies in this region will not be significant when the intervention is implemented because the number of unintended pregnancies is comparatively low from the start in the status quo coverage. However, when we increase the coverage to 55%, the number of wanted pregnancies will also be reduced, from which the greater proportion of the reduction in complicated pregnancies and maternal deaths is derived in this region, allowing it to be the region where the total health gain is highest.

Scaling up modern contraceptives has been found to be cost-effective by other economic modeling studies. Creating universal access to contraceptives in Uganda was found to be cost-effective and cost saving compared to the then existing contraceptive program. It resulted in a 0.37 incremental disability-adjusted life expectancy with a cost of $49 lesser than the program in place (33). Similar findings were also seen in another study conducted in Uganda and Indonesia. In that study, rather than universal access, the interventions increased modern contraceptive coverage from the status quo level by 25%, 50%, 75%, and 100%. The study had robust finding that the interventions were cost saving almost 100% of the time during the probabilistic sensitivity analysis (34). Even though the results of my probabilistic sensitivity analysis do not result in cost-effectiveness 100% of the time, they are still robust in that most of the time the intervention is cost saving. The results are thus comparable with those of the above-mentioned studies.

If the assumptions and model estimates used in this study are valid, health sector officials in Ethiopia, both at the national and regional level, may find these results relevant and might use them as supporting evidence to convince the government that investing more in modern contraceptives would result in better health benefits, reduced geographic inequality, and saved money. Looking into the results of the national model, an investment of US$20 million per year yields a cost saving of approximately US$1.4 million and improved health outcomes, such as an estimated 21,000 fewer unintended pregnancies, 2,770 averted abortions, close to 28,000 averted pregnancy complications, and 170 fewer maternal deaths.

Since this intervention is cost saving, it suggests that scaling up modern contraceptives to 55% prevalence is good value for money. However, the decision by policymakers to shift money from other health interventions to scaling up modern contraceptives requires consideration of other factors, such as the intervention's impact on financial risk protection and equitable distribution across socioeconomic statuses (35, 36).

One published economic evaluation study conducted at the national level in Ethiopia to check the cost-effectiveness of scaling up coverage of maternal and neonatal health services by 20% from the baseline showed that most of the health interventions included in the study, with the exception of calcium supplementation for preeclampsia and eclampsia, were cost-effective (based on specified GDP criteria for cost-effectiveness), some highly so. However, none of the interventions included in the study were identified as cost saving (37). As suggested for the economically evaluated interventions in the study by Memirie et al., modern contraception is an acceptable health intervention in the context of Ethiopia and is already part of the essential health service package there. However, the findings of this study also suggest that scaling up is worthy of consideration.

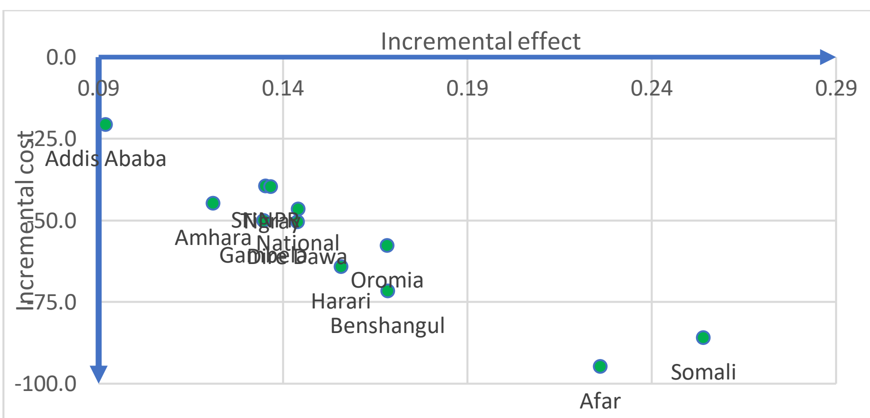


Figure 12. Incremental effect and incremental cost in all regions resulting from the intervention

One of the strengths of this study is the fact that it is the first subnational cost-effectiveness analysis of the scaling up of modern contraceptive coverage, at least in low- and middle-income countries. As discussed above, the cost-effectiveness of scaling up modern contraceptives has been examined by few economic evaluation studies. However, given the wide range in modern contraceptive coverage between regions within a country, the interventions have the possibility of different outcomes in different regions. Thus, the fact that this study is subnational makes it more informative with regard to the details of the cost- effectiveness of the intervention. As shown in Figure 12, Afar and Somali are far to the right on the cost-effectiveness plane, showing that the intervention is most cost-effective there, and that Addis Ababa is close to the origin, showing that the intervention is least cost-effective there.

Cost data are mostly from local, Ethiopian studies, with the exception of the cost data for demand generation, which came from a neighboring country. The proximity of the data source may make the study more useful for local decision makers than studies using cost data from other, more distant sources. Economic evaluation studies carried out with cost data from other countries are relatively difficult to use as evidence for local decision making (38). Thus, this study has greater value in this regard.

In this study, I have followed CHEERS format, which is the recommended reporting guideline for economic evaluation. Consequently, the study can be easily understood and evaluated by the economic evaluation study community, which will make it easier to compare the results with other economic evaluation studies. This is another strength of this study.

The study also has some limitations, however. One of these is that the benefits of contraceptives considered in this study were solely health benefits concerning the aversion of unintended pregnancies and related outcomes. Cost effectiveness analysis applied to health outcome only will underestimate the overall value of the intervention (39). Contraceptives have other health benefits to women, however, such as reducing the risk of endometrial and ovarian cancers, contributing to the treatment of menstrual-related symptoms, and preventing sexually transmitted diseases. Using contraceptives also helps to reduce child deaths by enabling mothers to improve the care given to children (40). Progress in gender equality gained because of better education and economic empowerment are also among important non-health benefits of contraceptive utilization (9) that were not incorporated into this study. On the other hand, there are also potential health-related risks with prolonged use of different types of modern contraceptive methods. Increased risk of breast cancer and impact on bone mineral density are encountered while using pills, and there is risk of pelvic inflammatory disease with the use of IUDs. These disadvantages of contraceptives were also not incorporated into this study (40). However, such disadvantages do not, I believe, outweigh the above-mentioned benefits; indeed, overall, my model may have underestimated the potential cost-effectiveness of scaling up modern contraceptive coverage.

A further limitation is that the study considered an increase in modern contraceptive coverage from a low initial rate, such as 1%, to a relatively high level of coverage (55%), and this may be unrealistic from a short-term perspective. I also assumed an instantaneous scale-up in modern contraceptive coverage and that such coverage remained constant throughout the whole cycle, which is not realistic. This was done to create a similar target coverage for the regions. Had I applied a constant rate of increment in coverage per year, the inter-regional differences in coverage would have remained the same at the end of the cycle, making equalization of coverage among regions impossible and comparison unfeasible. Changing the model structure and scaling-up pathways could have a substantial impact on the total costs, thus affecting the results of the cost-effectiveness analysis.

My study also did not consider the increasing marginal cost of scaling up modern contraceptives. The cost needed to increase coverage from 10 to 20 and from 40 to 50 was assumed to be the same in this study because of the absence of trusted local marginal cost data. However, marginal costs will not be constant. The study may thus overestimate the cost-effectiveness of the intervention. It would be much better to consider the incorporation of data collection on marginal costs in future models to determine the subnational cost-effectiveness of scaling-up interventions.

The fact that the model did not consider method mix of modern contraceptive methods, changing over the years as per the Ministry of Health's plan, is another limitation of this study. The lack of trusted local cost data and the complexity of incorporating the cost variation along with the change in method mix were the reasons for the exclusion of this consideration. In this study, the cost of contraception is one of the parameters to which the ICER value is sensitive; thus, the cost I used may have led to under- or overestimating the cost-effectiveness of the intervention. This should be considered in future modeling practice.

This study might have had a better evidence base had the cost data not been secondary. Primary cost data collection in all regions was beyond the scope and timeframe of this thesis. In addition, the absence of some regional data, such as age-specific transition probabilities and regional cost variations, persuaded me to compute them with some assumptions. Even though I tried to make my assumptions as close to reality as possible, the lack of data suggests that my results should be interpreted with caution.

The Wafula et al. study from which I extracted the cost data of demand generation is from Kenya. It was conducted to assess the contextual variation in costs for a community health strategy and not specifically for modern contraceptive demand generation. Thus, the cost of demand generation could be higher or lower and may affect the budget estimates I have produced. Kenya's urban/rural and the urban/nomadic area cost relation may also be different from Ethiopia's. Thus, the impact of variation in this cost data could be large and especially significant in regions like Somali where the increment in contraceptive coverage depends on demand generation. Thus, my choice of data from the Kenyan study may have had a definite impact on the regional analysis of the intervention's cost-effectiveness.

Finally, my results indicate that the federal government and partner organizations should focus on scaling up modern contraceptive coverage in all regions to address unmet need. In regions like Somali, however, increasing coverage would not be enough, and increasing demand should be given priority while also addressing the unmet need.

7. Conclusion

Scaling up and equalizing modern contraceptive coverage in all regions of Ethiopia is cost-effective and could also be cost saving both at the regional and national levels. In addition to the enormous health benefits that will be gained, regional governments will save money by investing in increased coverage of modern contraception. Although the intervention has good value for money, it is also necessary to look at other factors, such as the impact on financial risk protection, before shifting money from other areas of investment to this intervention. The results of this study can serve as evidence for budget appraisals if the assumptions are considered valid.

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Annex 1: CHEERS Checklist

ISPOR CHEERS Task Force Report, Consolidated Health Economic Evaluation Reporting Standards (CHEERS)—Explanation and Elaboration

Section/item	Item no.	Recommendation	Reported on page no./line no.
Title and abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms, such as "cost-effectiveness analysis," and describe the interventions compared.	Cover page
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	iii-v
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions	1-5/
Methods			
Target population and subgroups	4	Describe characteristics of the base-case population and subgroups analyzed, including why they were chosen.	6/11
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	NA
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	6/11
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	6/10
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	6/5

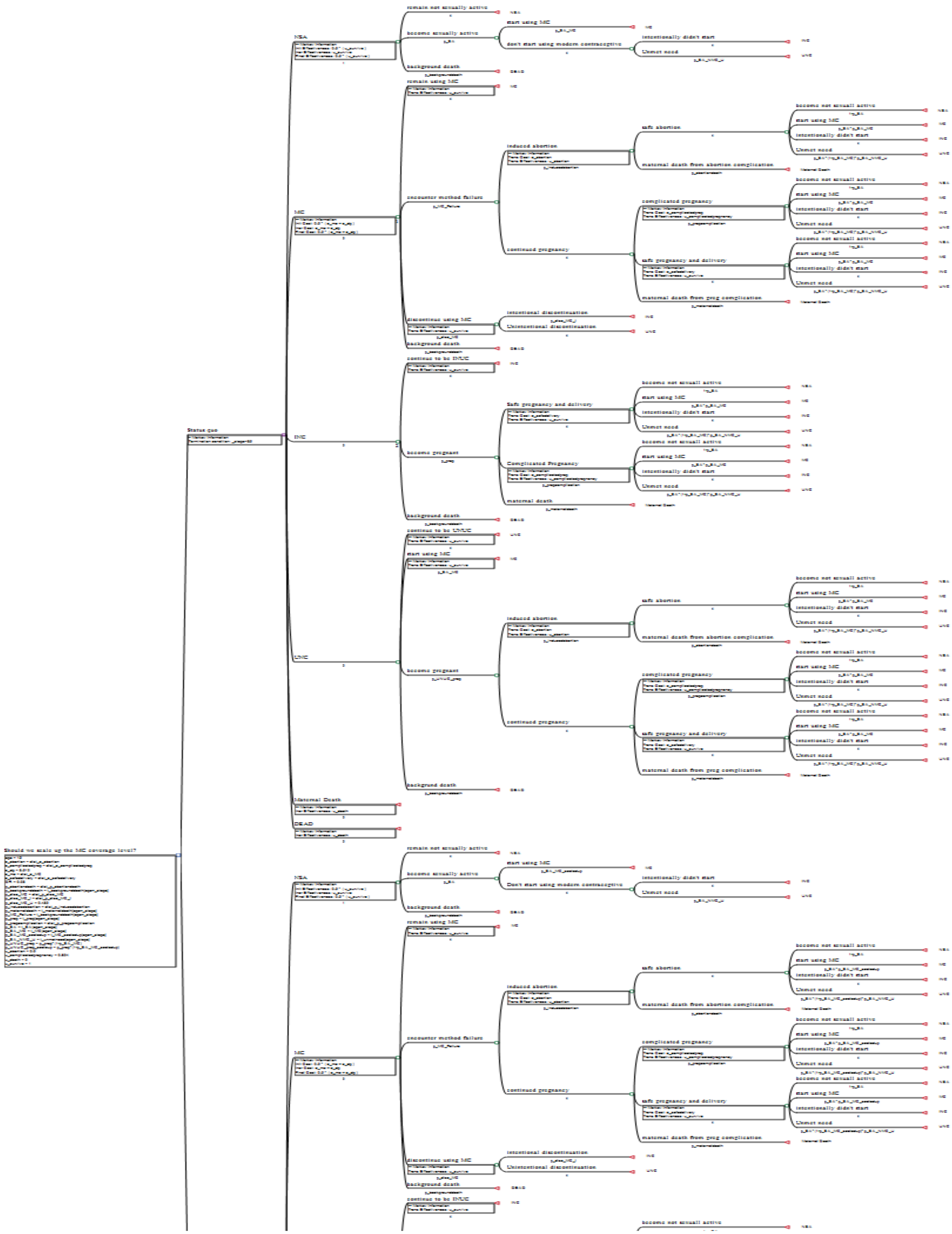
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	6/22
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	6/15
Measurement of effectiveness	11a	*Single study-based estimates*: Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	11/2
	11b	*Synthesis-based estimates*: Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	NA
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	NA
Estimating resources and costs	13a	*Single study-based economic evaluation:* Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	12/4
	13b	*Model-based economic evaluation*: Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	NA
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	13/15

Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended	8
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	8-9
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half-cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	10-13
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	11
Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	16-17
Characterizing uncertainty	20a	*Single study-based economic evaluation:* Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact	NA
		of methodological assumptions (such as discount rate, study perspective).	20
	20b	*Model-based economic evaluation:* Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	20
Characterizing heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between	

		subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information	20
Discussion			
Study findings, limitations, generalizability, and current knowledge	22	Summarize key study findings and describe how they support the conclusions reached. Discuss limitations and the generalizability of the findings and how the findings fit with current knowledge.	24
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	NA
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	

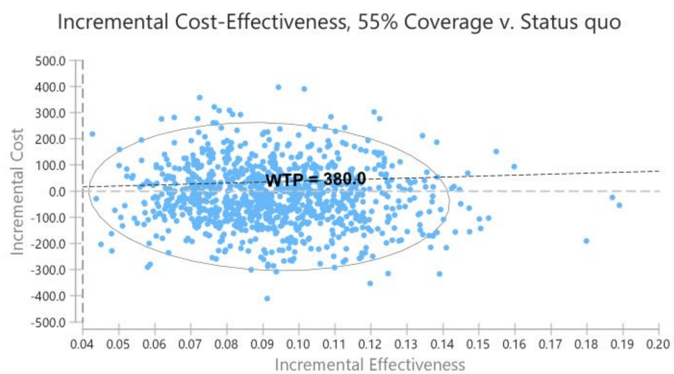
Annex 2: Markov model

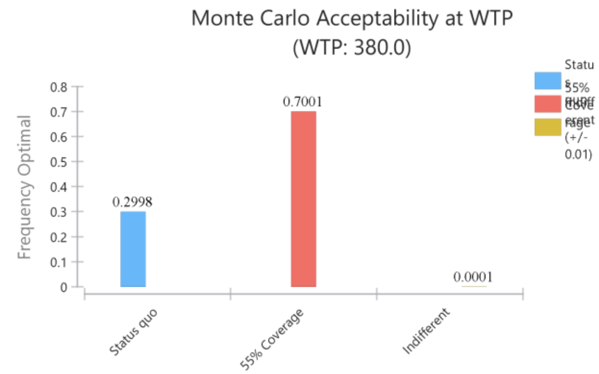
Figure 12. Markov model used in this study

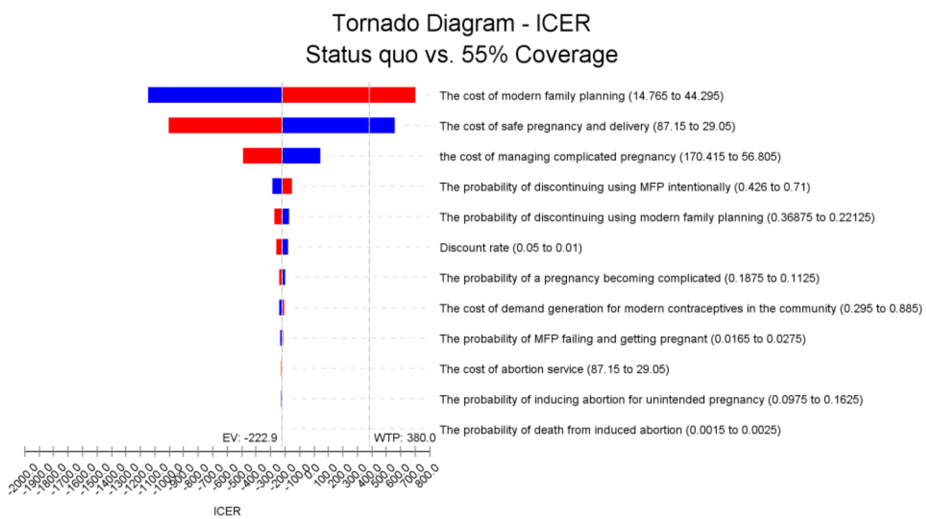


Annex 3: Probabilistic sensitivity analysis of regional models

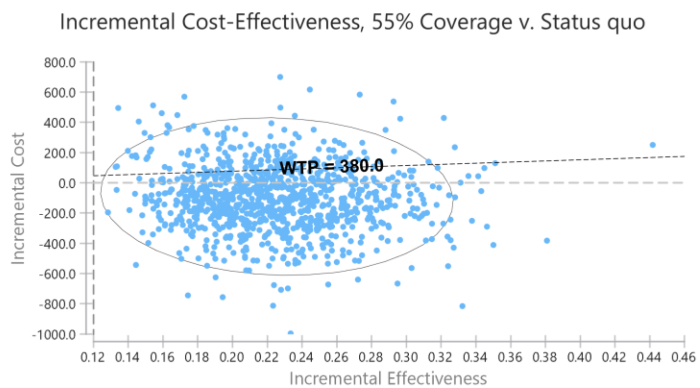
Addis Ababa: 70%



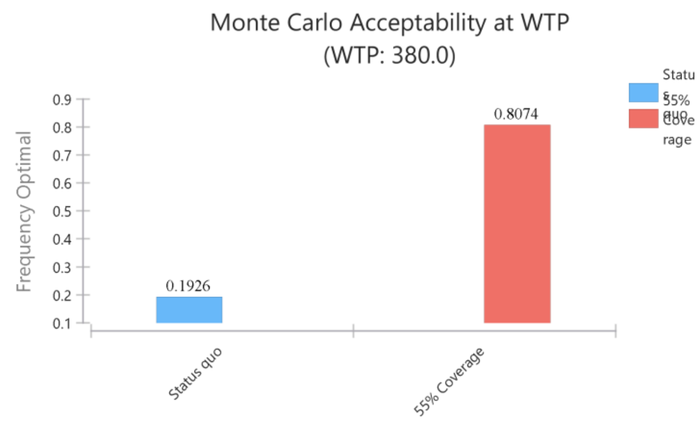




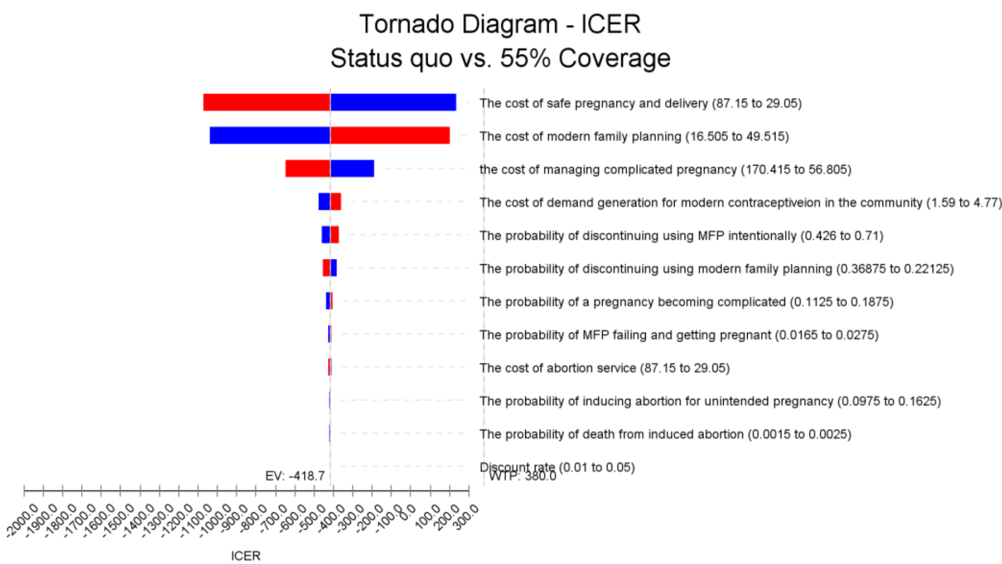
Afar: 80.7%



Incremental Cost-Effectiveness, 55% Coverage v. Status quo
WTP = 380.0
Incremental Cost
Incremental Effectiveness

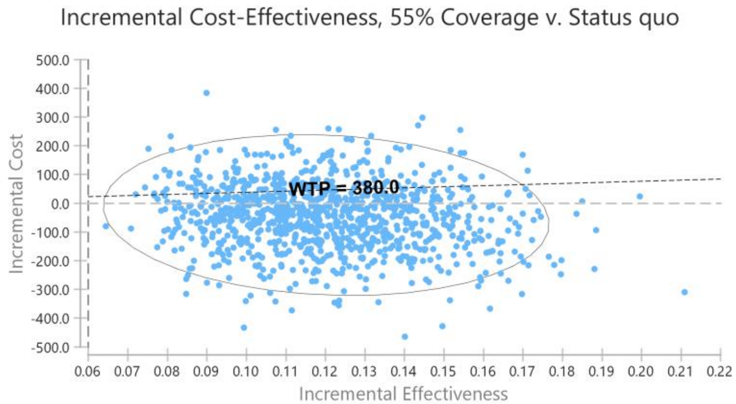


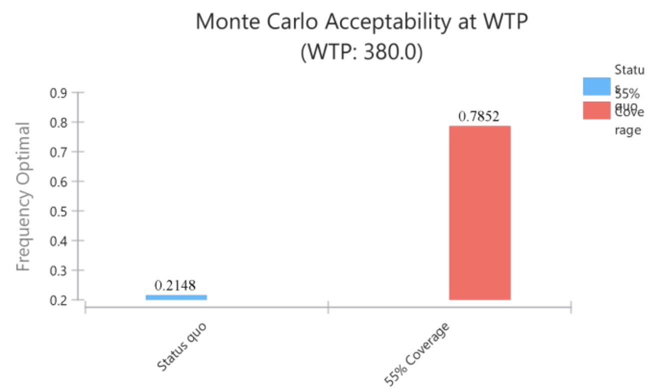
Monte Carlo Acceptability at WTP
(WTP: 380.0)
Frequency Optimal
0.1926
0.8074
Status quo
55% Coverage

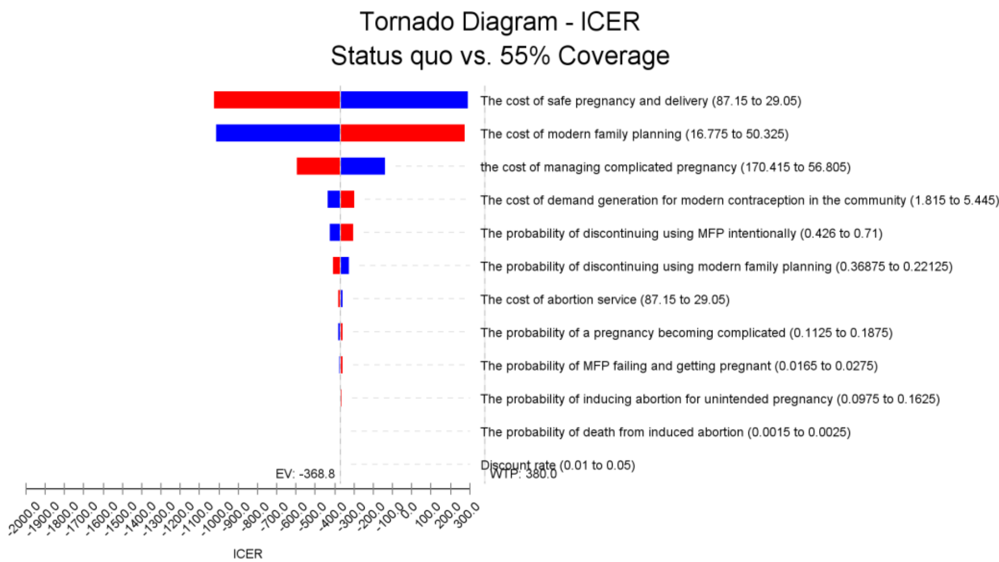


Tornado Diagram - ICER
Status quo vs. 55% Coverage
The cost of safe pregnancy and delivery (87.15 to 29.05)
The cost of modern family planning (16.505 to 49.515)
the cost of managing complicated pregnancy (170.415 to 56.805)
The cost of demand generation for modern contraceptiveion in the community (1.59 to 4.77)
The probability of discontinuing using MFP intentionally (0.426 to 0.71)
The probability of discontinuing using modern family planning (0.36875 to 0.22125)
The probability of a pregnancy becoming complicated (0.1125 to 0.1875)
The probability of MFP failing and getting pregnant (0.0165 to 0.0275)
The cost of abortion service (87.15 to 29.05)
The probability of inducing abortion for unintended pregnancy (0.0975 to 0.1625)
The probability of death from induced abortion (0.0015 to 0.0025)
Discount rate (0.01 to 0.05)
EV: -418.7
WTP: 380.0
ICER

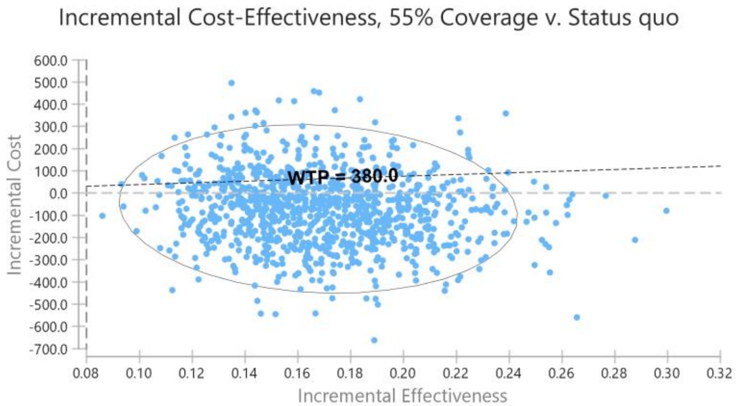
Amhara: 78.5%

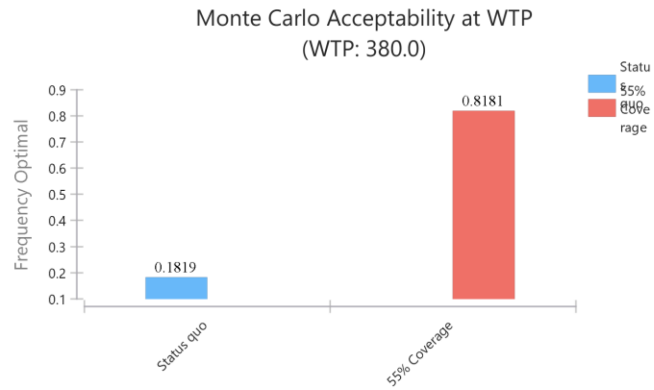

Incremental Cost-Effectiveness, 55% Coverage v. Status quo
Incremental Cost
Incremental Effectiveness
WTP = 380.0
500.0
400.0
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
-400.0
-500.0
0.06 0.07 0.08 0.09 0.10 0.11 0.12 0.13 0.14 0.15 0.16 0.17 0.18 0.19 0.20 0.21 0.22

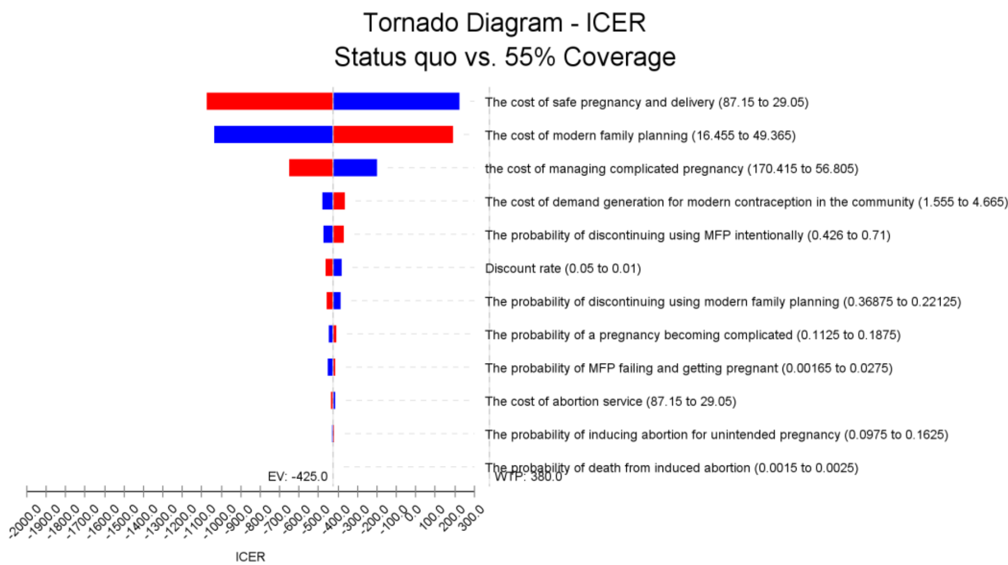

Monte Carlo Acceptability at WTP
(WTP: 380.0)
Frequency Optimal
0.2148
0.7852
Status quo
55% Coverage
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2


Tornado Diagram - ICER
Status quo vs. 55% Coverage
The cost of safe pregnancy and delivery (87.15 to 29.05)
The cost of modern family planning (16.775 to 50.325)
the cost of managing complicated pregnancy (170.415 to 56.805)
The cost of demand generation for modern contraception in the community (1.815 to 5.445)
The probability of discontinuing using MFP intentionally (0.426 to 0.71)
The probability of discontinuing using modern family planning (0.36875 to 0.22125)
The cost of abortion service (87.15 to 29.05)
The probability of a pregnancy becoming complicated (0.1125 to 0.1875)
The probability of MFP failing and getting pregnant (0.0165 to 0.0275)
The probability of inducing abortion for unintended pregnancy (0.0975 to 0.1625)
The probability of death from induced abortion (0.0015 to 0.0025)
Discount rate (0.01 to 0.05)
EV: -368.8
WTP: 380.0
ICER

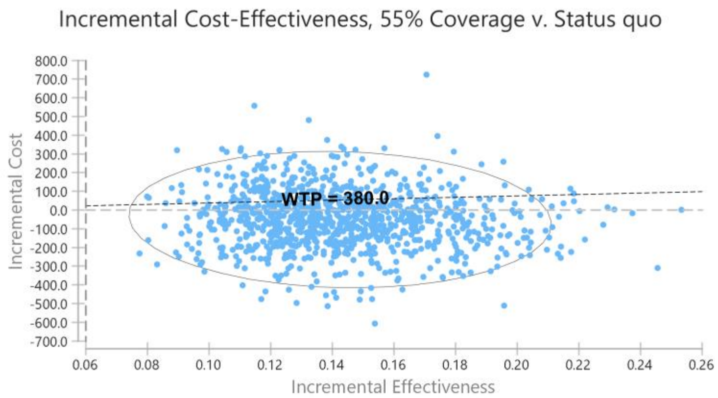
Benishangul: 81.1%

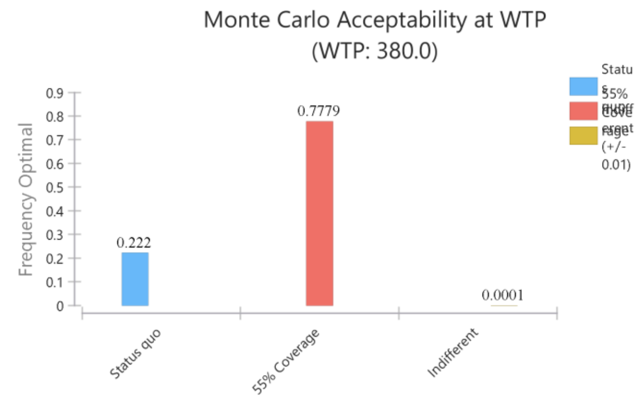


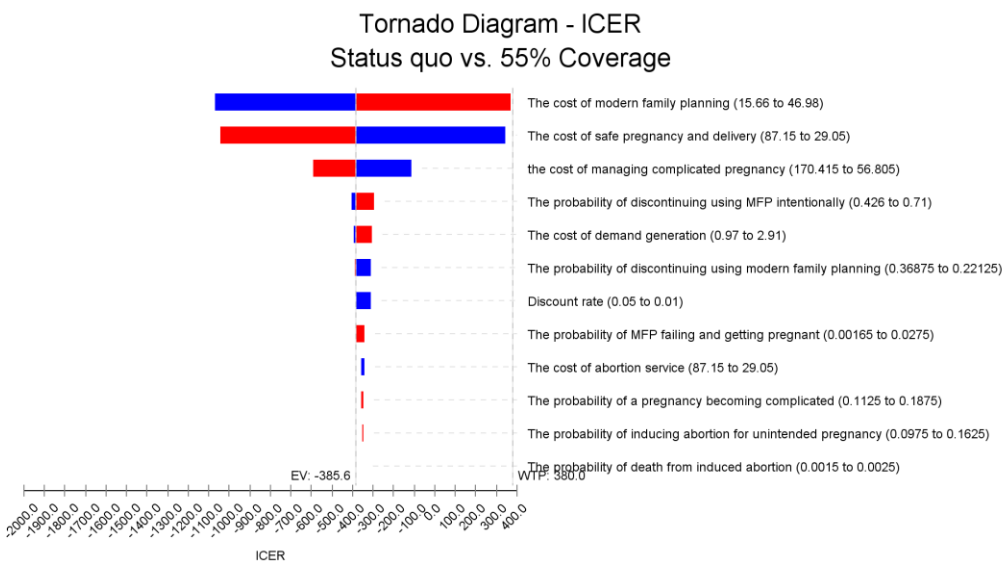




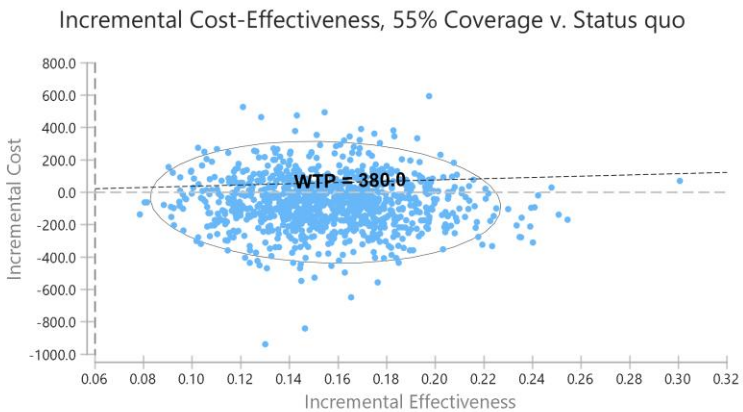
Dire Dawa: 77.8%

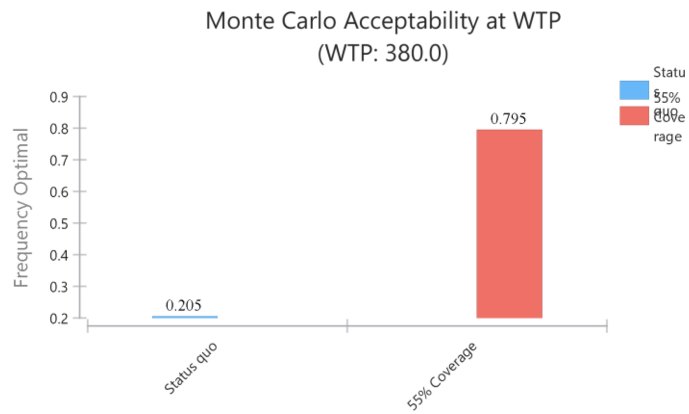


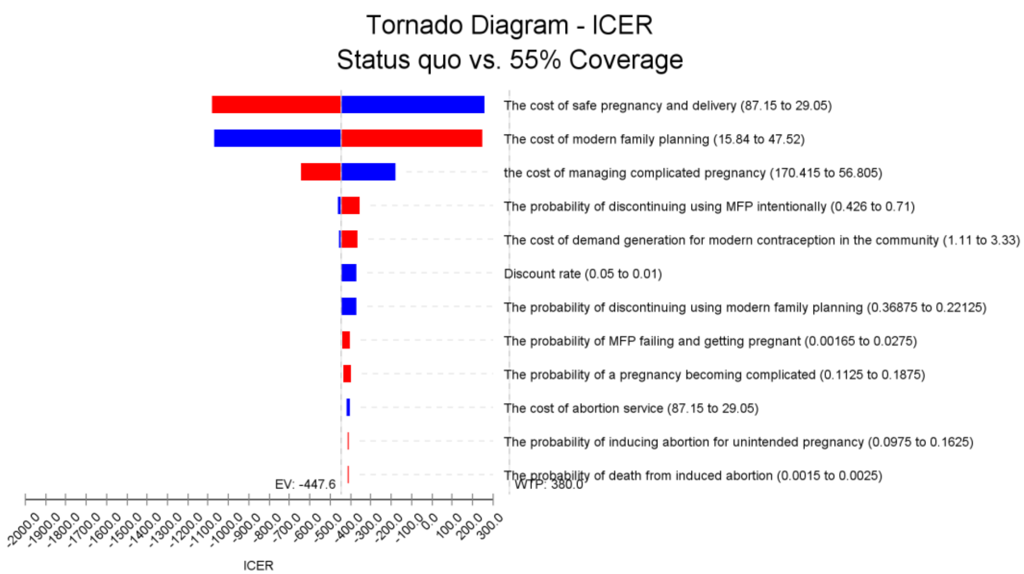




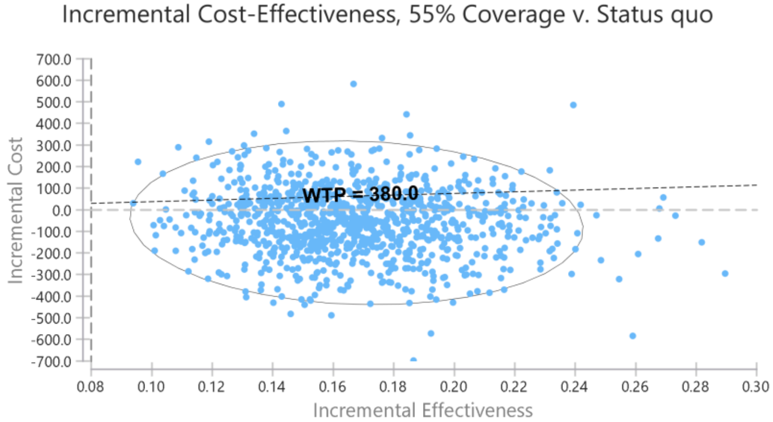
Harari: 79.5%

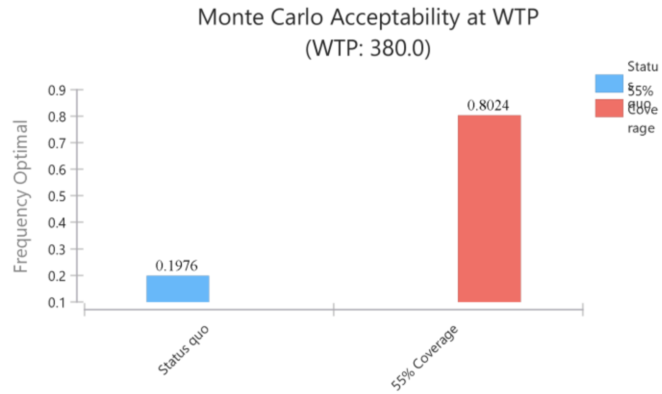

Incremental Cost-Effectiveness, 55% Coverage v. Status quo
Incremental Cost
Incremental Effectiveness
WTP = 380.0

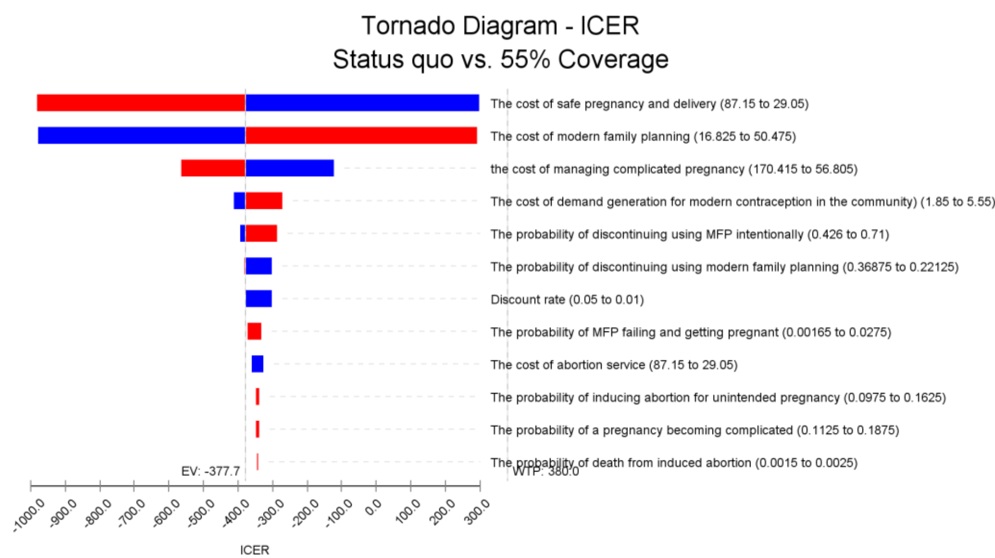

Monte Carlo Acceptability at WTP
(WTP: 380.0)
Frequency Optimal
0.205
0.795
Status quo
55% Coverage


Tornado Diagram - ICER
Status quo vs. 55% Coverage
The cost of safe pregnancy and delivery (87.15 to 29.05)
The cost of modern family planning (15.84 to 47.52)
the cost of managing complicated pregnancy (170.415 to 56.805)
The probability of discontinuing using MFP intentionally (0.426 to 0.71)
The cost of demand generation for modern contraception in the community (1.11 to 3.33)
Discount rate (0.05 to 0.01)
The probability of discontinuing using modern family planning (0.36875 to 0.22125)
The probability of MFP failing and getting pregnant (0.00165 to 0.0275)
The probability of a pregnancy becoming complicated (0.1125 to 0.1875)
The cost of abortion service (87.15 to 29.05)
The probability of inducing abortion for unintended pregnancy (0.0975 to 0.1625)
The probability of death from induced abortion (0.0015 to 0.0025)
EV: -447.6
WTP: 380.0
ICER

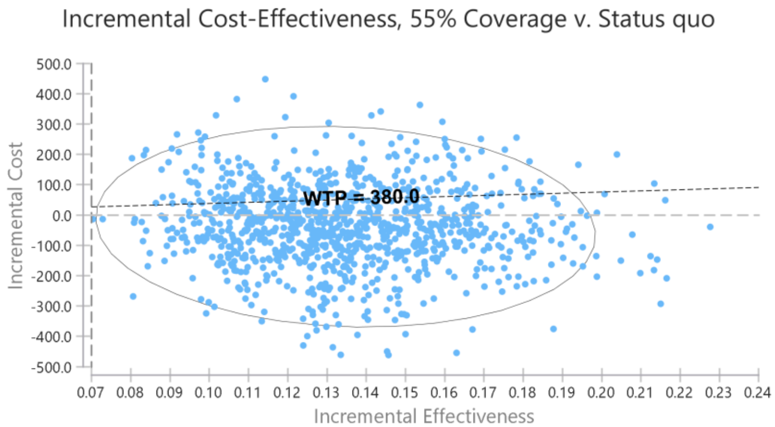
Oromia: 80.2%

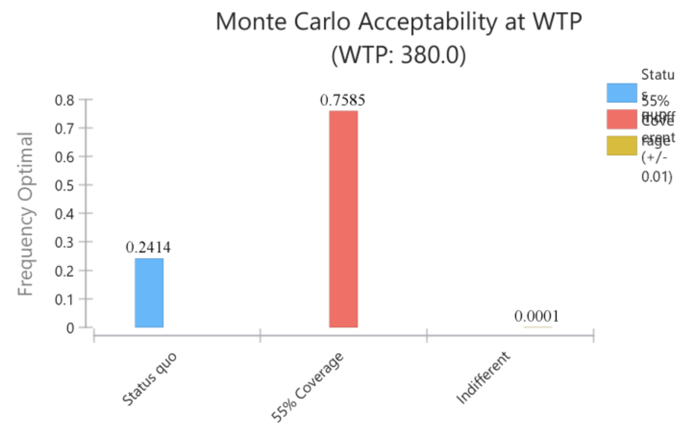

Incremental Cost-Effectiveness, 55% Coverage v. Status quo
WTP = 380.0
Incremental Cost
Incremental Effectiveness
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
-400.0
-500.0
-600.0
-700.0
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
0.26
0.28
0.30

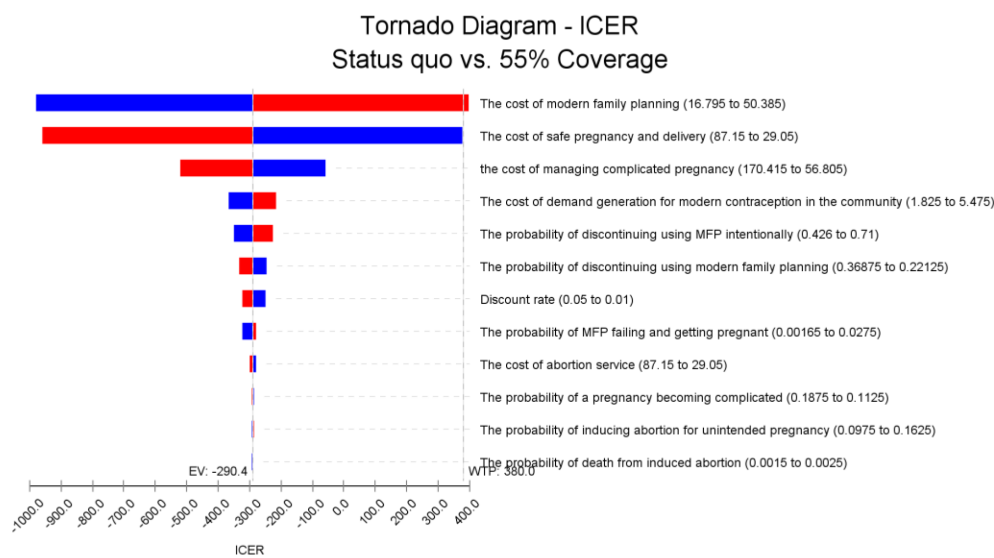

Monte Carlo Acceptability at WTP
(WTP: 380.0)
Frequency Optimal
0.1976
0.8024
Status quo
55% Coverage
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Tornado Diagram - ICER
Status quo vs. 55% Coverage
The cost of safe pregnancy and delivery (87.15 to 29.05)
The cost of modern family planning (16.825 to 50.475)
the cost of managing complicated pregnancy (170.415 to 56.805)
The cost of demand generation for modern contraception in the community) (1.85 to 5.55)
The probability of discontinuing using MFP intentionally (0.426 to 0.71)
The probability of discontinuing using modern family planning (0.36875 to 0.22125)
Discount rate (0.05 to 0.01)
The probability of MFP failing and getting pregnant (0.00165 to 0.0275)
The cost of abortion service (87.15 to 29.05)
The probability of inducing abortion for unintended pregnancy (0.0975 to 0.1625)
The probability of a pregnancy becoming complicated (0.1125 to 0.1875)
The probability of death from induced abortion (0.0015 to 0.0025)
EV: -377.7
WTP: 380.0
-1000.0
-900.0
-800.0
-700.0
-600.0
-500.0
-400.0
-300.0
-200.0
-100.0
0.0
100.0
200.0
300.0
ICER

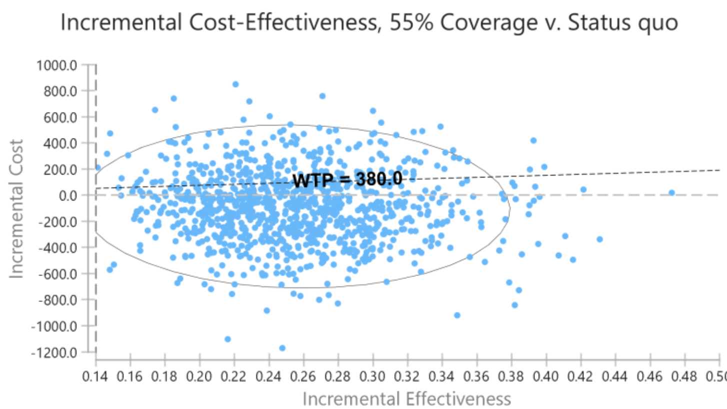
SNNP: 75.85%

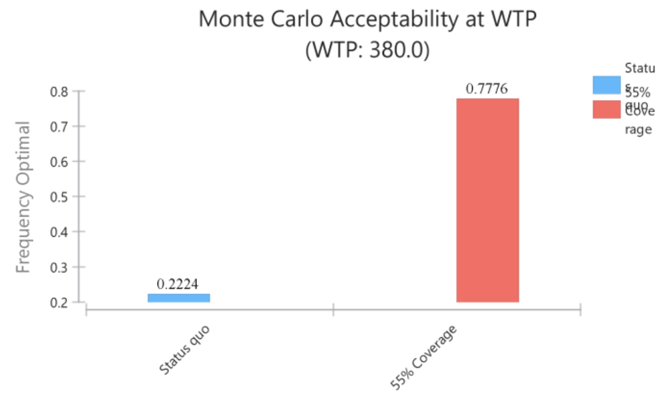

Incremental Cost-Effectiveness, 55% Coverage v. Status quo
WTP = 380.0
Incremental Cost
Incremental Effectiveness
500.0
400.0
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
-400.0
-500.0
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14
0.15
0.16
0.17
0.18
0.19
0.20
0.21
0.22
0.23
0.24

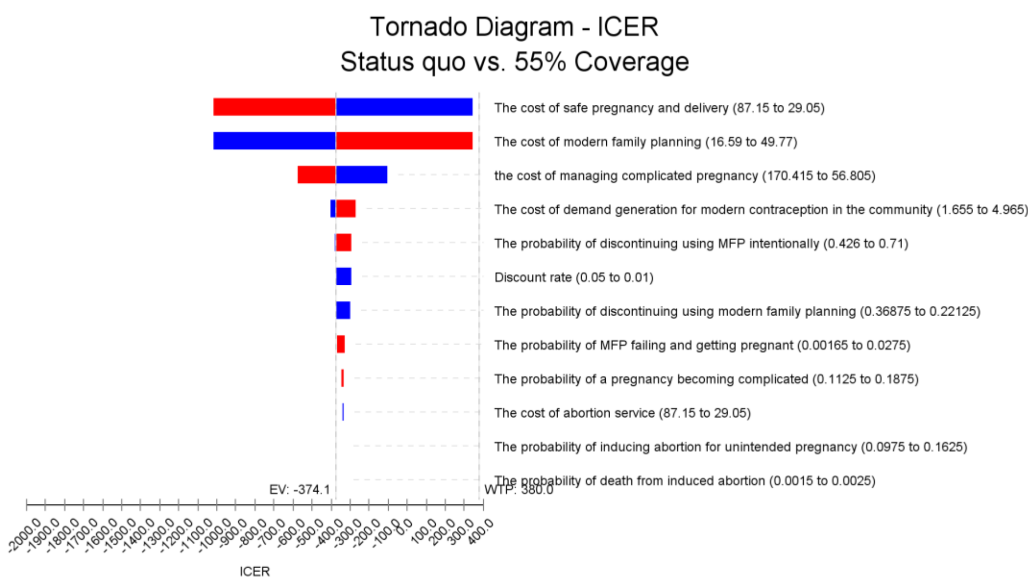

Monte Carlo Acceptability at WTP
(WTP: 380.0)
Frequency Optimal
0.2414
0.7585
0.0001
Status quo
55% Coverage
Indifferent
(+/-
0.01)


Tornado Diagram - ICER
Status quo vs. 55% Coverage
The cost of modern family planning (16.795 to 50.385)
The cost of safe pregnancy and delivery (87.15 to 29.05)
the cost of managing complicated pregnancy (170.415 to 56.805)
The cost of demand generation for modern contraception in the community (1.825 to 5.475)
The probability of discontinuing using MFP intentionally (0.426 to 0.71)
The probability of discontinuing using modern family planning (0.36875 to 0.22125)
Discount rate (0.05 to 0.01)
The probability of MFP failing and getting pregnant (0.00165 to 0.0275)
The cost of abortion service (87.15 to 29.05)
The probability of a pregnancy becoming complicated (0.1875 to 0.1125)
The probability of inducing abortion for unintended pregnancy (0.0975 to 0.1625)
The probability of death from induced abortion (0.0015 to 0.0025)
EV: -290.4
WTP: 380.0
ICER

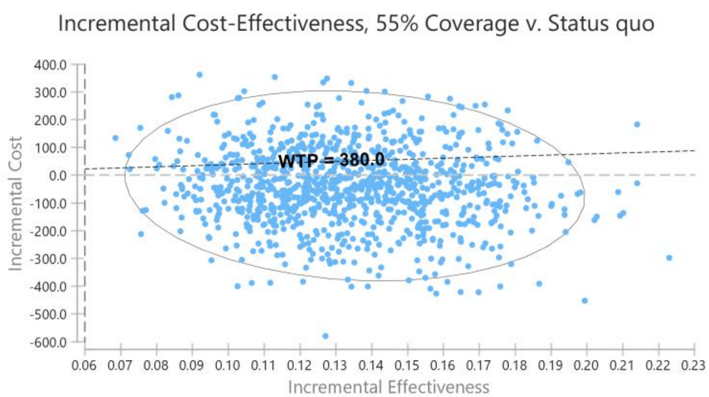
Somali: 77.7%


Incremental Cost-Effectiveness, 55% Coverage v. Status quo
WTP = 380.0
Incremental Cost
Incremental Effectiveness

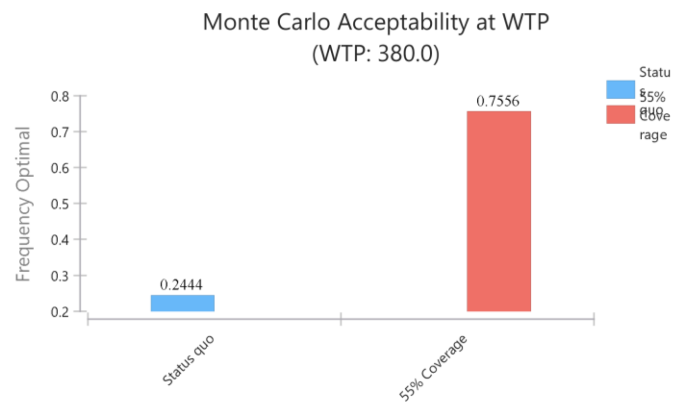

Monte Carlo Acceptability at WTP
(WTP: 380.0)
Frequency Optimal
0.2224
0.7776
Status quo
55% Coverage


Tornado Diagram - ICER
Status quo vs. 55% Coverage
The cost of safe pregnancy and delivery (87.15 to 29.05)
The cost of modern family planning (16.59 to 49.77)
the cost of managing complicated pregnancy (170.415 to 56.805)
The cost of demand generation for modern contraception in the community (1.655 to 4.965)
The probability of discontinuing using MFP intentionally (0.426 to 0.71)
Discount rate (0.05 to 0.01)
The probability of discontinuing using modern family planning (0.36875 to 0.22125)
The probability of MFP failing and getting pregnant (0.00165 to 0.0275)
The probability of a pregnancy becoming complicated (0.1125 to 0.1875)
The cost of abortion service (87.15 to 29.05)
The probability of inducing abortion for unintended pregnancy (0.0975 to 0.1625)
The probability of death from induced abortion (0.0015 to 0.0025)
EV: -374.1
WTP: 380.0
ICER

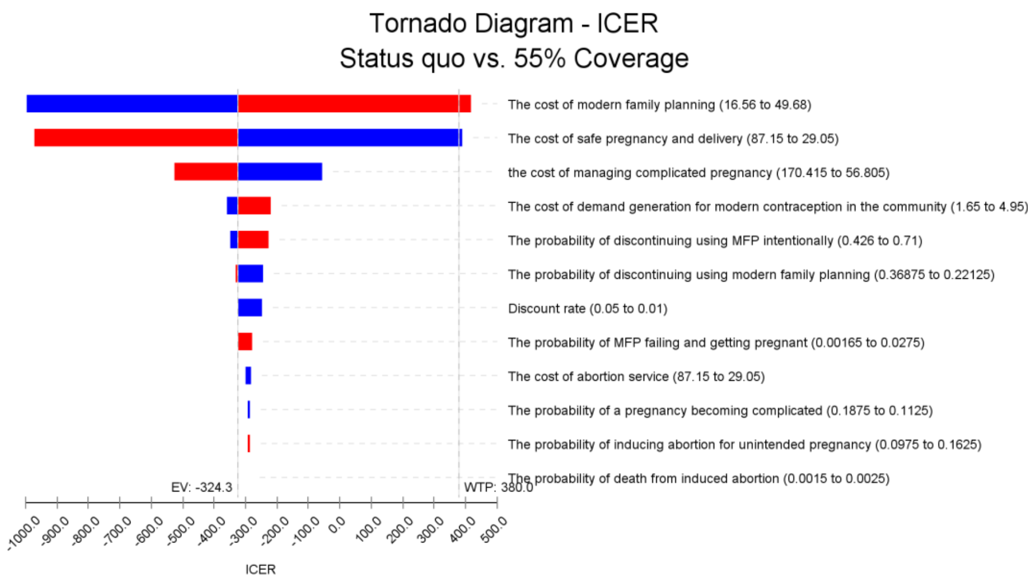
Tigray: 75.6%



Incremental Cost-Effectiveness, 55% Coverage v. Status quo
WTP = 380.0
Incremental Cost
Incremental Effectiveness

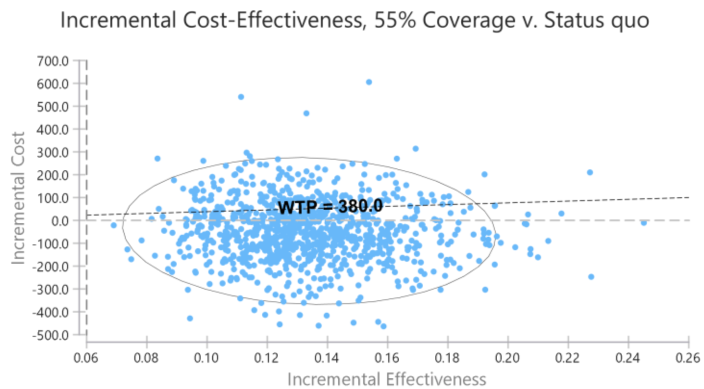


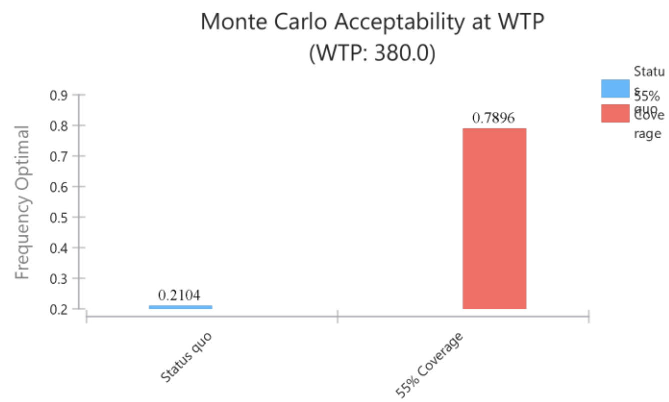
Monte Carlo Acceptability at WTP
(WTP: 380.0)
Frequency Optimal
0.2444
0.7556
Status quo
55% Coverage



Tornado Diagram - ICER
Status quo vs. 55% Coverage
The cost of modern family planning (16.56 to 49.68)
The cost of safe pregnancy and delivery (87.15 to 29.05)
the cost of managing complicated pregnancy (170.415 to 56.805)
The cost of demand generation for modern contraception in the community (1.65 to 4.95)
The probability of discontinuing using MFP intentionally (0.426 to 0.71)
The probability of discontinuing using modern family planning (0.36875 to 0.22125)
Discount rate (0.05 to 0.01)
The probability of MFP failing and getting pregnant (0.00165 to 0.0275)
The cost of abortion service (87.15 to 29.05)
The probability of a pregnancy becoming complicated (0.1875 to 0.1125)
The probability of inducing abortion for unintended pregnancy (0.0975 to 0.1625)
The probability of death from induced abortion (0.0015 to 0.0025)
EV: -324.3
WTP: 380.0
ICER

Gambela: 79%


Incremental Cost-Effectiveness, 55% Coverage v. Status quo
WTP = 380.0
Incremental Cost
Incremental Effectiveness


Monte Carlo Acceptability at WTP
(WTP: 380.0)
Frequency Optimal
0.2104
0.7896
Status quo
55% Coverage

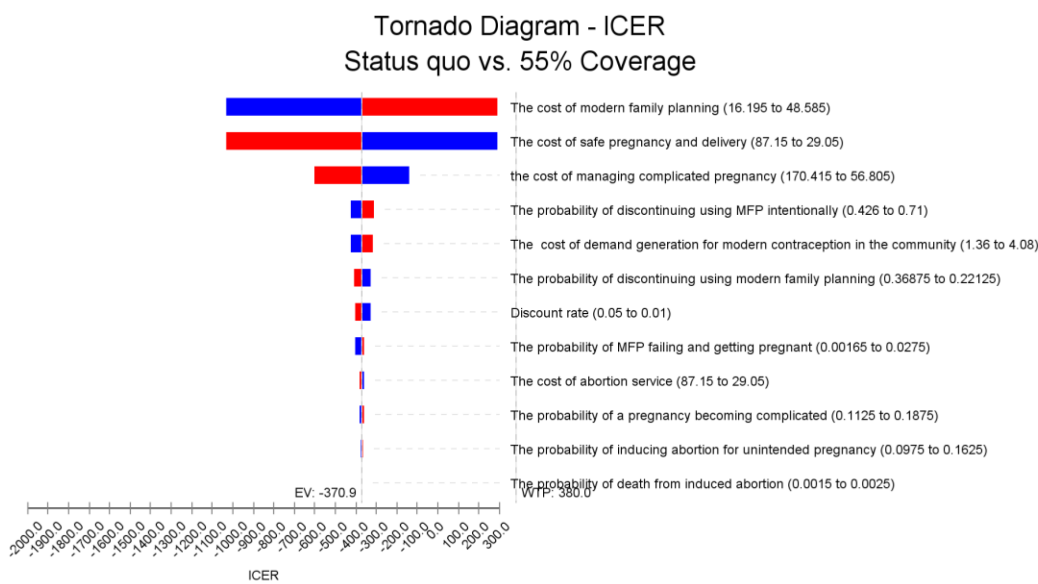

Tornado Diagram - ICER
Status quo vs. 55% Coverage
The cost of modern family planning (16.195 to 48.585)
The cost of safe pregnancy and delivery (87.15 to 29.05)
the cost of managing complicated pregnancy (170.415 to 56.805)
The probability of discontinuing using MFP intentionally (0.426 to 0.71)
The cost of demand generation for modern contraception in the community (1.36 to 4.08)
The probability of discontinuing using modern family planning (0.36875 to 0.22125)
Discount rate (0.05 to 0.01)
The probability of MFP failing and getting pregnant (0.00165 to 0.0275)
The cost of abortion service (87.15 to 29.05)
The probability of a pregnancy becoming complicated (0.1125 to 0.1875)
The probability of inducing abortion for unintended pregnancy (0.0975 to 0.1625)
The probability of death from induced abortion (0.0015 to 0.0025)
EV: -370.9
WTP: 380.0
ICER

Table 9. Current modern contraceptive coverage and 15-year-old female population projected by CSA, used for the analysis of clinical outcomes and budget impact

Region	Status quo modern contraceptive coverage	2016 15-year-old female population
Harari	20.2	2,492
Dire Dawa	18.8	4,660
Gambela	26.5	4,427
Somali	1.0	48,993
Addis Ababa	23.2	23,269
Ben. Gumuz	21.9	12,124
Afar	10.0	16,481
Tigray	24.5	59,510
Amhara	33.7	230,771
SNNP	26.5	232,254
Oromia	20.9	421,979
National	24.8	1,056,960