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Valuing health services using benefit transfer: Cross-subsidization of cataract surgeries in Ethiopia

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Abstract

The employment of manual small incision cataract surgeries has dramatically increased the number of surgeries. However, poverty and the associated lack of access have resulted in a persistent underprovision of cataract surgeries in Ethiopia. Cross-subsidization has the potential as a self-sustaining mechanism to increase service uptake of cataract surgeries. To measure the feasibility of cross-subsidization of cataract surgeries in Ethiopia, we use benefit transfer analysis to find the estimated mean cross-subsidization margins ranging from $10 to $37 per surgery.

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1. Introduction

In 1999, the World Health Organization and the International Agency for the Prevention of Blindness launched the program, VISION 2020: The Right to Sight, with the ambitious goal of eliminating avoidable blindness by 2020 (Pizzarello et al. 2004). As a consequence of greater care interventions, the age-adjusted proportion of blind or visually impaired people with a preventable or treatable cause is slowly declining over time. The prevalence of blindness and its causes vary by region, with the decline in age-standardized prevalence of blindness due to cataracts being the greatest in Europe and Latin America. In east sub-Saharan Africa, the proportion of blindness attributable to cataracts increased from 38.9% in 1990 to 44.7% in 2015 (Flaxman et al. 2017). Ethiopia is of interest within this region since it has a population of approximately 112 million (World Bank 2020) and has one of the world's highest rates of blindness. According to a survey conducted in 2005-2006, 1.6% of Ethiopia's population is blind, nearly three times the world average. In 2007, approximately 50% of blindness (more than 890,000 individuals) was attributed to cataracts (Berhane et al. 2007).

Ethiopia has made significant strides in addressing visual impairment due to innovations in surgical techniques and the effectiveness of non-governmental organizations such as HCP Cure Blindness (HCP), which has provided a crucial component in delivering direct services and support via training and sustainable infrastructure (HCP Cure Blindness 2022a). Critical to these programs is the employment of manual small incision cataract surgeries (MSICS), which are a safe, relatively inexpensive, and effective means for visual rehabilitation of cataract patients and are suitable for high volume settings (Gogate et al. 2007; Muralikrishnan et al. 2004; Ruit et al. 2007; Tabin et al. 2008; Venkatesh et al. 2016; Venkatesh et al. 2012). In 2019, approximately 30% of cataract surgeries in Ethiopia were provided by the HCP, which uses MSICS as opposed to the phacoemulsification method. With an estimated backlog of over 800,000 cataract-related blindness cases in Ethiopia and only slightly over 80,000 cataract surgeries provided each year, the annual rate of new cataract cases will continue to outpace the number of surgeries performed (HCP Cure Blindness 2020). The backlog is exacerbated by the number and distribution of health care specialists. Palmer et al. (2014) noted that the practitioner growth in Ethiopia is expected to outpace the population growth rate after 2020; however, there is a problem with the distribution of medical specialists such as ophthalmologists. In 2007, only 17% of doctors practiced in rural locations, partly due to the deployment process.

For Ethiopia, previous benefit-cost studies in low-income rural areas showed that the estimated benefits were lower than the estimated costs (Gessesse and Demissie 2014; Seid et al. 2021). However, our focus is not specifically on the benefit-cost analysis for the low-income individuals who are visually impaired due to cataracts. Instead, our concentration is on the viability of the provision of cataract surgery using a model similar to that employed in India and Nepal, in which higher-income individuals receiving surgery pay a higher fee, thus subsidizing lower-income patients. To evaluate the potential of cross-subsidization of cataract surgeries in Ethiopia, we estimate the net benefits of cataract surgeries using benefit transfer analysis based on willingness to pay estimates from various low to middle-income countries and cost estimates for cataract surgeries. Our analysis supports the viability of the cross-subsidization of cataract surgeries for rural outreach centers. However, we do not

imply that it can be the sole source to overcome the backlog of cataract surgeries given the magnitude of the problem.

2. Cross-Subsidization

For the neediest population, contingent valuation analysis-based studies generate relatively low willingness to pay estimates for cataract surgeries in Ethiopia. Specifically, Gessesse and Demissie (2014) and Seid et al. (2021) show that the estimated benefits are lower than the costs of the surgeries. Since this segment of the Ethiopian population is unlikely to be able to afford cataract surgeries, cross-subsidization from revenue generated by higher income cataract patients is a potential means to increase access. Cross-subsidization in healthcare occurs when the healthcare provider prices some services below cost and compensates the loss with profits from other services. As with the Aravind Eye Care System, perhaps best known for providing low-cost cataract surgeries, cross-subsidization may occur with multi-tiered services. Through Aravind Eye Care System's multi-tiered pricing system, patients with a greater ability to pay are offered extra amenities such as private rooms or special meals at a higher fee. The revenue generated is used to subsidize patients with a lower ability to pay. Under this system, about 40% of patients pay the full fee of $200 US, 30% pay a reduced fee (averaging $18), and 30% receive the surgery at no cost(Broyles et al. 2013; Gupta et al. 2018; Brilliant and Brilliant 2007). The Tilganga Institute of Ophthalmology (TIO), located in Kathmandu, Nepal, has examined and treated more than 400,000 eye patients and conducted around 65,000 minor and major surgeries annually since its inception in 1994 (World Health Organization 2021). Over 50% of the services of the TIO are paid for in full, with over 40 percent of the services provided for free, and the rest are substantially subsidized (Broyles et al. 2013).

Although Seid et al. (2021) conclude that developing a cost-recovery model with multi-tiered packages is essential to increase the uptake of cataract surgeries since standalone outreach cataract clinics in Ethiopia are not viable options, multi-tiered packages do not necessarily involve amenity rich services employed by the Aravind Eye Care System. On the contrary, cross-subsidization of cataract surgeries may involve revenue from standard services, such as phacoemulsification with the implantation of a foldable intraocular lens, and subsidizing the lower cost service of the MSICS with a PMMA lens.[1] For example, the TIO's revenue from profitable services subsidizes its outreach program in which lower-income patients receive lower cost MSICS with a PMMA lens. This is relevant since, with the Himalayan Cataract Project (HCP) partnership, the TIO has been able to engage in successful outreach programs in Nepal. The HCP also engages in outreach operations in Ethiopia (Chang 2013; Nikpoor et al. 2018).

Since price discrimination is crucial to cross-subsidization, estimating the willingness to pay for moderate to high-income patients in Ethiopia is essential given that the existing Ethiopian willingness to pay studies have only focused on outreach patients with low per capita income (Gessesse and Demissie 2014; Seid et al. 2021). Without direct estimates for the willingness to pay for moderate to high-income Ethiopian patients, we use benefit estimate transfer as a cost-effective means to estimate these values. From the two broad types of benefit transfer, unit value and function transfer, we use unit value transfer. Unit value

[1] Worldwide, phacoemulsification with the implantation of a foldable intraocular lens is the procedure of choice since it leads to better visual acuity as compared to MSICS with a PMMA lens (Hennig et al. 2014).

transfer is the appropriate approach as the previous contingent valuation studies are lacking the relevant co-variants that are necessary for function transfer. Due to the additional uncertainty associated with benefit transfer analysis, we evaluate the cross-subsidization margins under various distributional assumptions.[2]

3. Willingness to Pay Studies

In order to estimate the marginal benefits for middle-income cataract patients in Ethiopia, we use prior willingness to pay values starting with a discussion of Gessesse and Demissie (2014). They interviewed 134 patients at rural outreach clinics in southwest Ethiopia and found that 76% were willing to pay for cataract surgical services, with a mean WTP of $12. As theory suggests, those with greater wealth, as indicated by farmland ownership or self-identifying as "not employed but not financially dependent," were willing to pay more. Males were significantly more likely to be willing to pay for the surgery than women. The questions used to indicate income in this study suggest the difficulty of conducting surveys in low-income regions, where standard income questions may not be appropriate.

Noting that WTP for cataract surgery varies by location, with urban-centered patients more willing to pay, Seid et al. (2021) conducted a willingness to pay study in rural northwest Ethiopia. Using a bidding-game CV format, the authors first determined whether respondents were willing to pay for the surgery and then estimated the maximum WTP. The mean WTP is well below the actual cost of the surgery. Therefore, the authors propose an inclusive cost-recovery system modeled after India's Aravind Eye Care System. The willingness to pay for enhancements to cataract surgical services suggests a possible solution to funding surgeries in low-income regions. Ko et al. (2012) estimated the willingness to pay for various amenities in a predominantly rural county in Guangdong Province, China. Patients were offered four hypothetical enhancements: food, transportation, surgery performed by a senior surgeon, and an imported lens rather than the standard Chinese-made lens. Of 426 survey participants, 73% were willing to pay for at least one surgical enhancement. Among all participants, including those with zero WTP, mean WTPs were under $1 for food, $1 for transportation, $2 for a senior surgeon, and $33 for an imported lens. The authors emphasize that these results indicate that cataract surgery programs can increase the number of free or subsidized surgeries by offering enhancements for existing patients (Ko et al. 2012). In the Baiyin district of northwestern China, Zhang et al. (2021) found that 60.1% of the participants were willing to pay some amount for the cataract surgery median with a willingness to pay of $78.

Islam et al. (2019) surveyed 556 patients at five eye care hospitals in Dhaka, Bangladesh, to determine WTP for two types of cataract surgical services. Using a contingent valuation approach, they found a mean willingness to pay $93 for MSICS, representing 12 days of household income. WTP for phacoemulsification was $129, or 16 days of household income. Household income is the most crucial determinant of WTP. Given the low cost of MSICS, the authors conclude that it is feasible to provide patients with access to such surgeries with cross-subsidization. He et al. (2007) examined the willingness to pay for cataract surgeries in rural China. Using a combination of open-ended and payment card questions, they found

[2]For a comprehensive review of the uncertainty associated with the value transfer estimation, see Navrud and Ready (2007).

that 79% of the 325 patients surveyed were willing to pay for cataract surgery, with an average WTP of $55. This represents approximately 11% of annual income. As expected, WTP was positively related to literacy and income and negatively associated with age (He et al. 2007). In contrast, Shrestha et al. (2004) found that only 43.6% of 78 patients surveyed were willing to pay for cataract surgical services in the Kathmandu valley of Nepal. The most common reason for the low willingness to pay was poverty. Both studies found that illiterate patients were less likely to be willing to pay, suggesting that education about the causes of blindness and the benefits of cataract surgery may affect WTP. Of respondents with zero WTP, 24% in the Chinese study and 11% in Kathmandu cite the belief that surgery is unnecessary or ineffective in treating cataracts (He et al. 2007; Shrestha et al. 2004).

Geneau et al. (2008) take a qualitative approach to studying willingness to pay in Tanzania. Using extensive interviews of 47 patients and open-ended questions, they examined the willingness to accept and pay for cataract surgical services. Not surprisingly, they found that the primary determinant of WTP was the perceived need for the surgery. Thus, patients with bilateral cataracts and those hoping to return to work were more willing to pay. Although no actual dollar value of WTP was estimated, these respondents were more likely to give replies such as "one must do what it takes" to pay whatever is required. Individuals with good sight in one eye, the elderly, and women who could continue to work in the home with severely limited sight are less likely to accept surgery. Numerous studies have found that the perceived effectiveness of the surgery is an important factor (He et al. 2007; Shrestha et al. 2004; Geneau et al. 2008). The decision to undergo surgery is not made solely by the patient but by the family since many did not have the financial means to pay for the surgery themselves, even at subsidized prices. Instead, they relied on support from relatives (Geneau et al. 2008). In the northwest Nigerian Zamfara state, where 70% of the population live on less than $1/day, Ibrahim et al. (2018) found a median willingness to pay for cataract surgery of $19. Sixty-four percent of the participants said they would ask their family or friends to pay on their behalf, with twenty-six of the participants stating that they would need to sell possessions. Only 8% of the patients reported having enough money to pay for surgery.

Dean et al. (2012) elaborate on this problem in a study conducted in Malawi. In a pilot study of 30 participants, they found that most would not or could not answer a question related to monetary wealth. The authors concluded that 80% of the patients who received care at the clinic were subsistence farmers with little or no regular monetary income. In the final survey administered for the study, participants were instead asked to estimate the quantities of agricultural products (maize, tobacco, beans) and livestock (chickens, goats, cattle) they owned. Based on a survey of 212 patients, they found that 64% were willing to pay something in cash, with a mean WTP of $10 US. 65% were willing to pay in kind either in addition to or in place of cash payment. Again, WTP increased with increasing material wealth.

Wang et al. (2015) extend the estimation of WTP to address the difficulties of providing cataract surgical services in a system based on uniform pricing so that a patient pays the same fee regardless of the surgeons' professional level. Using a survey of 211 patients, researchers focused on two questions: would the patient be willing to pay for cataract surgery, and would the patient be willing to pay an additional fee to have that surgery performed by a senior physician. The results indicate that 89.6% of patients would be willing to pay for

the surgery (median WTP = $968). 50.7% said they would be willing to pay an additional fee to have a senior doctor (median WTP = $81).

4. Analysis

To consider the inherent uncertainty associated with our estimations, we use Monte Carlo simulations under various scenarios. The uncertainty has two sources: the uncertainty associated with the willingness to pay and the uncertainty related to the marginal costs of the surgeries. To perform the Monte Carlo simulations, we seeded the distributions with mean and standard deviation values for the marginal benefits and marginal costs.

For the seed values of the marginal benefits, we eliminate the WTP estimate of Shrestha et al. (2004) due to a subjective, and non-probabilistic sampling method. Also, the WTP estimate of $1,077 from Wang et al. 2015 was excluded as an outlier since it involved specialized services in one of the most prosperous cities in China, Guangzhou ("National Bureau of Statistics of China 2019). After eliminating these two estimates and applying the appropriate conversions, we arrived at a mean value of $53. Based on the range rule, since 99.7% of observations will lie within three standard deviations of the mean of a normal distribution, the implied standard deviation is $17.

It is important to note that, given that we are focused on the estimation of the willingness to pay for moderate to high-income patients in Ethiopia, Addis Ababa, the capital of Ethiopia, is probably a more relevant population for the estimation of WTP values than the values from the rural populations of Ethiopia and Malawi which have very low incomes (Gessesse and Demissie 2014, Seid et al. 2021 and Dean et al. 2012). The per capita income of Addis Ababa residents is not only higher than the national average but is also experiencing significant growth, and Addis Ababa is the location of multiple eye care centers that are partners with the HCP (Spaliviero and Cheru 2017; HCP Cure Blindness 2022b). However, there are currently no WTP studies for Addis Ababa. To capture the range of values that may reflect our target population, we use the similar values from Gessesse and Demissie (2014) and Dean et al. (2012) as our lower bound and Islam et al. (2019) as our upper bound. With the willingness to pay values for the rural populations underestimating the lower bound, the willingness to pay value of Dhaka, Bangladesh from Islam et al. (2019) is likely to overestimate the upper bound since the average household monthly income in the study was above the per capita income of Addis Ababa.[3]

For the marginal costs of the surgeries, we consider the characteristics of MSICS, which is the most common type of cataract surgery performed in developing countries. This surgical method has several benefits: it is fast, requires minimal equipment, and yields excellent visual outcomes with low rates of complications. In 2007, researchers estimated the cost per surgery to be $15 if the surgical consumables were reused, which is possible in high-volume programs (Gogate et al. 2007). Ruit et al. (2007) reported the per-case cost of surgical consumables to be $70 for phacoemulsification and $15 for MSICS. A significant factor driving the differences in overall costs is the cost of the intraocular lens, with foldable acrylic lens costing upwards of $52, which contrasts significantly with the less expensive PMMA lens at $5 (Ruit et al. 2007; Venkatesh et al. 2016). Beyond the cost differential associated

[3]In general, the empirical evidence suggests that international benefit transfer is as valid as intra-country transfer(Ready and Navrud 2006).

with the lenses, the phacoemulsification approach requires additional surgical consumables (Ruit et al. 2007; Venkatesh et al. 2016). For MSICS in a high-volume surgical center in India, the marginal cost per case is $17 (Muralikrishnan et al. 2004). After adjusting for inflation and changes in exchange rates, we find the marginal costs of MSICS range from $19 to $35. If costs are normally distributed, this implies that the mean of the MSICS values, $24, and the implied standard deviation, $4, based on the range rule.

In the base case, we conducted Monte Carlo simulations to generate distributions of values for the cross-subsidization margins with normality assumptions for both distributions (see Table I). One hundred thousand random draws were taken from each distribution, and the differences between marginal benefits and marginal costs were calculated to give us the cross-subsidization margins. In this case, we found the mean cross-subsidization margin to be $29, with a standard deviation of $17 and 97.72% of the values being positive in the 95% confidence interval.

Since Kolmogorov–Smirnov tests imply that the distributions of the marginal cost and the distribution of the marginal benefits are affected by the form of the distribution (normal vs. uniform), we perform additional simulations for both distributions and the associated combinations. In the second simulation, we maintain the normality assumption for the marginal benefit values and assume a uniform distribution for the marginal costs. As previously noted, after adjusting for inflation, the estimates of the marginal cost of cataract surgical services have a lower bound of $19 and an upper bound of $35. Assuming a uniform distribution, the implied mean is $27. The standard deviation of a uniform distribution is determined by the lower bound, a, and the upper bound, b, with $\sigma = \sqrt{\frac{(b-a)^2}{12}}$. The implied standard deviation of the marginal costs of the surgeries is $5. In this second scenario, with a normal distribution of the marginal benefits and a uniform distribution of the marginal cost, we found the mean cross-subsidization margin to be $26 with a standard deviation of $17 with 95.47% positive values in the 95% confidence interval.

Next, we perform simulations with an assumption of uniform distribution of the marginal benefits and an assumption of normally distributed marginal costs. If the marginal benefits are uniformly distributed, the implied mean is $58 with a standard deviation of $26. The Monte Carlo simulations result in a mean cross-subsidization margin of $37 with a standard deviation of $27. In the 95% confidence interval, 89.01% of the values are positive. In the final scenario, we perform the simulations while assuming uniform distributions for marginal benefits and marginal costs. In this scenario, the mean cross-subsidization margin is $31 with a standard deviation of $27 with 85.66% positive values in the 95% confidence interval. In our initial four scenarios, the estimated cross-subsidization margin ranges from $26 to $37.

To address the influence of higher willingness to pay values that may be inconsistent with marginal values in Ethiopia, we repeat the four simulations while varying the distributional assumptions for marginal benefits and marginal costs but eliminate the highest willingness to pay values (marginal benefit values). We eliminated the two similar high willingness to pay values, $104 and $100, from our sample, resulting in a mean seed value of $37 and a standard deviation of $14 under the assumption of normality. For the other two simulations that use a uniform distribution for the values of the marginal benefits, the mean seed value is $46 with a standard deviation of $20. In the four scenarios with the truncated sample of marginal

benefits, we repeat our Monte Carlo simulations with 100,000 draws. With the elimination of the two similar high willingness to pay values, the highest cross-subsidization margin drops by over 40%, from $37 to $22. The range of the mean values is $10 to $22, which is significantly lower than the initial range of $26 to $37. The percentage of the positive values also are decreased with only 74.71% positive in the worst-case scenario (normal distribution of benefits and uniform distribution of costs.)

Table I: Cross-Subsidization Margins (2020$)

Benefits: Normal Costs: Normal	Base Case	Truncated Case
Mean	28.70	12.46
Std Dev	17.09	14.81
CV	0.59	1.19
95% CI	[-4.81, 62.07]	[-16.63, 41.55]
Percent Positive in 95% CI	95.47	74.71
Benefits: Normal Costs: Uniform	Base Case	Truncated Case
Mean	25.88	9.57
Std Dev	17.36	15.19
CV	0.67	1.59
95% CI	[-8.26, 60.07]	[-20.33, 39.36]
Percent Positive in 95% CI	95.47	74.71
Benefits: Uniform Costs: Normal	Base Case	Truncated Case
Mean	37.47	21.97
Std Dev	26.56	19.81
CV	0.71	0.90
95% CI	[-10.45, $78.02]	[-11.27, 53.35]
Percent Positive in 95% CI	89.01	88.29
Benefits: Uniform Costs: Uniform	Base Case	Truncated Case
Mean	30.73	18.88
Std Dev	26.70	20.11
CV	0.87	1.06
95% CI	[-14.35, 76.06]	[-15.56, 53.64]
Percent Positive in 95% CI	85.66	79.33

5. Policy Implications and Conclusions

We conclude that increases in the provision of cataract surgeries via cross-subsidization in Ethiopia are viable, although there are still significant barriers to access to care. We find the estimated mean cross-subsidization margins to range from $10 to $37. By incorporating various distributional assumptions, we allow for a great degree of uncertainty. While previous Ethiopian cataract studies focused only on willingness to pay for lower-income patients, our

contribution is the evaluation of the potential for the cross-subsidization of lower-income patients. With positive cross-subsidization margins, we argue that it is feasible for the revenue from higher-income patients to cover the services for a portion of the population whose willingness to pay is below the cost of surgeries.

The following caveats must be kept in mind. First, the level of benefits used in our study are likely to underestimate the general population's valuation of cataract surgeries for various reasons. The existing willingness to pay estimates for Ethiopia are based solely on the benefits to the low-income patients and do not necessarily include the benefits that accrue to individuals who are associated with the surgery recipient. With this positive consumption externality, the benefits of cataract surgeries are not solely experienced by the recipient of the surgery but include benefits that flow to others. Post-surgery, the recipient is more self-sufficient and independent, which allows the family member, the former caregiver, to engage in productive activities (Gordois et al. 2012;Taylor et al. 2006; Frick et al. 2005). In general, the importance of improvements in health outcomes is spotlighted in the work by Jamison et al. (2013). They showed that approximately 24% of the growth in income in low and middle-income countries between 2000 and 2011 was due to better health outcomes. It is unlikely that the consumption externality is reflected in the willingness to pay of the individuals.

Second, improvements in access to cataract surgeries require coordinated efforts in terms of political and financial commitment. Sabanayagam and Cheng (2017) summarize Flaxman et al. (2017) by noting that there remains a "substantial gap" between the goal set by VISION 2020 and the results achieved thus far. The Aravind Eye System and Tilganga Institute of Ophthalmology, both private institutions, have greater flexibility in reappropriating revenue to outreach programs. Replicating the success of these institutions is difficult since the main health care partners of the Himalayan Cataract Project are public institutions that face barriers or are not incentivized to reallocate resources to nonprofit outreach programs Nikpoor et al. (2018).

Finally, value transfer studies may be considered a first approximation or a rough estimate in evaluating a given policy due to the unavoidable presence of transfer errors. We see the direct estimation of the benefits of cataract surgeries in Addis Ababa via contingent valuation as an essential next step in assessing the cross-subsidization of cataract surgeries in Ethiopia.

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