Using choice modelling to identify popular and affordable alternative interventions for schistosomiasis in Uganda

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ONLINE APPENDIX

1. Summary of Schisosomiasis life cycle

The life cycle of *S. mansoni*, requires both a mammal, in this case humans, and freshwater snails, *Biomphalaria* spp, as hosts.[1] When a human enters infected water, schistosome cercariae penetrate the skin and find their way into the bloodstream and reside in the capillaries surrounding the intestines. Male and female worms pair-up and sexually produce eggs. Eggs are excreted in the human stool. If eggs reach bodies of fresh water, they hatch into miracidia. Miracidia infect intermediate *Biomphalaria* hosts. The schistosomes reproduce asexually in the snail with one miracidium capable of developing into thousands of cercariae. These cercariae are released into the water and burrow directly into human skin to complete the life cycle.

2. Description of study communities

We collected choice data from households in three remote villages in the Mayuge District of Uganda, located on the shore of Lake Victoria with schistosomiasis prevalence rates of ~75% in adults and ~90% in children (Chami *et al*., 2015). Our study was conducted in three rural communities in the Mayuge District of Uganda: Bugoto (A and B)[2], Musubi and Bwondha, all located on the shores of Lake Victoria. This district lies southeast of the capital Kampala and consists of seven subcounties and 289 communities. The latest census data, from 2017, show that 2,472 and 1,221 individuals live in Bugoto A and B respectively; 3,560 live in Musubi; and 14,649 live in Bwondha.

Many households living in this area rely on water from the lake for domestic chores (e.g. washing, cooking, bathing) as well as for their livelihoods (e.g. fisherfolk, almost exclusively fishermen, or clothes washers, predominantly washerwomen, known as *dhobies*). Water sources that are considered safe include taps that provide filtered lake water, or boreholes

[1] There are many types of *Schistosoma* spp which cause schistosomiasis. This study focused only on *Schistosoma mansoni*. Hereby, schistosomiasis means the disease only caused by *Schistosoma mansoni*.
[2] The community of Bugoto is split into Bugoto A and B. Bugoto A is on a peninsula along the lake shore and Bugoto B is approximately one km inland from Bugoto A.

and wells, which both provide access to groundwater. Currently, households can pay between 100-200 Ugandan shillings (approximately £0.02) for a 20-litre jerry can of water at the tap. In addition to requiring payment, our ethnographic work indicates that these water sources are frequently locked, broken, empty, far from an individual's home, provide hard water that is difficult to lather, provide salty water and/or are slow running, particularly in the dry season. There is therefore a limited reliance on these infrastructures.

Each of the villages have very limited sanitation in place. In Bugoto B and Musubi, many households have access to a private or shared latrine, with some public latrines located in schools and churches. In Bugoto A and Bwondha, there also exist landlord-owned latrines as well as some public latrines, which can be used in exchange for a small fee. These tend to be located on the lake shore and in public gathering places (e.g. schools, churches, market places). Existing public latrines, and some private latrines, are very poorly maintained, and may well be unsafe for the user, particularly for smaller children if the holes are too big, or conversely, difficult to use if the holes are too small. Therefore, even when communities have public and/or private latrines, many households lack access to a conveniently located, adequately maintained, safe, and unlocked latrine.[3]

3. Study design

Two Lusoga-speaking ethnographers (one male, one female) undertook six weeks REA in each community, collecting data through focus group discussions, in-depth interviews, guided transect walks and structured observation of water contact and other sites. In September 2018 the choice experiment was piloted by two Ugandan researchers (led by one of the co-authors, LM) familiar with the villages and fluent in the local language (Lusoga). During this time, it

[3] Ethnographic research undertaken to inform these DCEs suggested that reasons for open defecation extend beyond simply access to (safe) latrines; however, access remained a key concern for study participants.

was ensured that questions were understood as intended and that all the attributes (and associated images) were well comprehended. After this pilot we chose to remove one of the RTO attributes that was causing confusion and replaced it with the maintenance attribute.

A second pilot study was undertaken in December 2018 (by LM) after survey adjustments were made, to ensure the survey had improved, and the newly added maintenance attribute image was understood. During this time, we also increased the upper monthly payment level and established baseline priors for the experimental design. The full study was administered in February 2019. Five Ugandan researchers were recruited to administer the survey who are fluent in Lusoga and were supervised by one of the co-authors (LM). Researchers spent one week in training and then one month surveying the three communities. Surveys were administered on tablets via Sawtooth Software's Computer Assisted Personal Interview interface (Sawtooth, 2018). After the first few days of surveying, we updated the priors of the experimental design. After the two pilot studies, the final survey was performed with the aim of understanding and quantifying community preferences for possible improvements to WASH resources.

4. Example choice card RTO

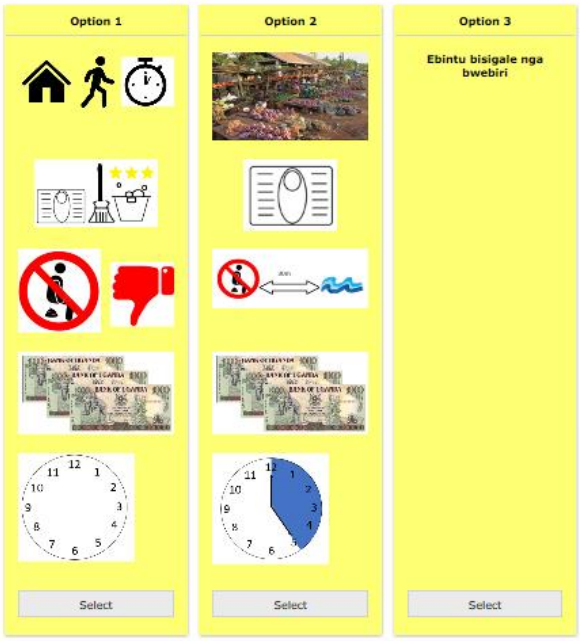

Figure A1. Risk to Others example choice card.

Notes: Option 1 involves: new latrines to be in the residential area within 5 minutes from your home, all latrines would be maintained to a high standard, fines for open defecation anywhere, UGX3,000/month, and 0 hours/week. Option 2 involves: new latrines at the market place, all latrines would be maintained like they are now, fines for open defecation within 30 m of the lake, UGX3,000/month, and 5 hours/week. Option 3 is translated as "I prefer none of these options".

5. Example choice card RTS

Figure A2. Example Risk to Self choice card.

Notes: Option 1 involves: lake water filtration site - water made safe for domestic chores but not drinking, 2 new water access points, daily public radio campaigns, UGX3,000/month, and 1 hour/week. Option 2 involves: tap with 10 jerry cans, 4 new water access points, monthly community village health team talks, UGX3,000/month, and 1 hour/week. Option 3 is translated as "I prefer none of these options".

6. Sample summary

Table A1. Summary of sample

Variables	Mean across sample
Village of respondent	
Musubi	0.105
Bugoto	0.305
Bwondha	0.581
Female	0.47
Year of education	
Less than Primary	0.515
Primary	0.38
Ordinary Secondary	0.08
Advanced Secondary	0.0094
Tertiary	0.0024
Household size	6.35
Children under 18	3.67
Children under 5	1.36
Occupation†	
Fisherfolk	0.25
Farmer	0.44
Local Business	0.17
Traders	0.09
Caregivers	0.06
Other	0.16
Unemployed	0.04
Age	
18-25	0.16
26-35	0.29
36-45	0.23
46-55	0.16
55+	0.12
I don't know	0.01
Daily personal income	UGX 7,703‡

†Individuals could report having more than one occupation and therefore this totals more than one.

‡Over 14% of individuals surveyed reported a zero-daily income, and the median daily income was UGX4,000 (£0.87).

7. Class membership variables

To estimate the ECLC model we considered several class membership co-variates as drivers of the class membership model (equation (7)). For each RTO and RTS dataset we consider two variables related to respondents' knowledge and behaviour. In the RTO case, this included respondent knowledge of how schistosomiasis is transmitted and whether respondents engage in an activity known to put others at risk of contracting schistosomiasis. More specifically, this second variable captured respondents who mentioned that they openly defecate when they are either at home or at work. These were asked as open-ended questions and were coded only if respondents mentioned specific answers in their response.

For the RTS data, we included a knowledge variable capturing whether they mention touching lake water as a means of how schistosomiasis is contracted. Second, we include a variable for submerged which indicates respondents who, the last time they were at the lake (or any natural water source), spent 15 minutes or more with at least their hands and/or feet submerged. For both risk scenarios we also included a dummy variable for being female and the sine hyperbolic transformation of income, as possible drivers of latent class membership. The co-variates are outlined in Table A2.

Table A2. ECLC model co-variates

Model	Variable name	Description	Mean across sample
RTO	Know about *S. mansoni* transmission	= 1 if respondent mentioned open defecation as transmission	0.55
RTO	Open defaecation	= 1 if respondent mentioned openly defecating at work or home	0.25
RTS	Know about *S. mansoni* transmission	= 1 if respondent mentioned 'Touching lake water'	0.55
RTS	Submerge > 15 min	= 1 if respondent spent more than 15 minutes with hands or feet submerged at their last water visit	0.40
RTO + RTS	Income	= sine hyperbolic transformation of income	8.42
RTO + RTS	Female	= 1 if respondent was female	0.47

Slightly more than half of the sample mentioned open defecation as the means by which schistosomiasis is transmitted. The second most mentioned response was through urinating in the lake (25%)[4] while 33% indicated not knowing how the parasite is transmitted.[5,6] Only 25% of the sample mentioned that they practice open defecation at home or at work; however, this may be underreported due to the possible stigma of admitting to this.[7] Of those who state that they openly defecate, 42.5% indicated not knowing that this can cause schistosomiasis transmission.

More than half of the respondents (55%), correctly mentioned that schistosomiasis is contracted through touching contaminated water. However, others stated that it is contracted through open defecation (25%), walking barefoot (18%), or drinking lake water (58%).[8] A total of 40% of our sample spent over 15 minutes in the water the last time they visited their most frequented natural water source. Looking only at the subset of these respondents, about half (53.5%) correctly stated how schistosomiasis is contracted, which is roughly the same percentage as over the whole sample. We take the sine hyperbolic transformation of income to account for the 14% of respondents who reported zero daily income.

[4] While S. *mansoni* is not transmitted through urination, another common species, *S. haematobium*, is transmitted via urine, although not found in this region.
[5] This is the percentage of respondents who said 'they did not know' when asked how the parasite is transmitted, not the percentage of respondents who incorrectly answered the question.
[6] Respondents could mention more than one method of how the parasite is transmitted, therefore this may not add up to 100.
[7] In focus groups, participants would state they had a latrine and a fellow participant would laugh and correct them. This suggests a desire to be perceived as someone who does not engage in open defecation to outsiders.
[8] Several of these incorrect suggestions are however transmission routes for other diseases. As this was an open-ended question, respondents may have mentioned more than one means of contracting schistosomiasis, therefore percentages do not add up to 100%.

8. ECLC membership co-variates RTO model

Table A3. ECLC membership co-variates RTO model

	Class1 (st. err)	z-value	Class2 (st. err)	z-value	Class3 (st. err)	z-value	Class4 (st. err)	z-value	Wald (p-value)
Intercept	1.96	1.07	-4.83	-1.15	-1.45	-0.44	4.33	2.56	15.04
	(1.828)		(4.212)		(3.341)		(1.697)		(0.001)
Know how schisto is spread	-0.42	-0.43	2.23	0.94	-1.60	-1.16	-0.21	-0.24	1.74
	(0.972)		(2.382)		(1.373)		(0.878)		(0.63)
Open defecation	-1.83	-1.62	2.17	1.30	-0.20	-0.12	-0.15	-0.18	3.74
	(1.127)		(1.677)		(1.722)		(0.814)		(0.29)
Income	-0.10	-0.89	0.14	0.55	0.02	0.15	-0.07	-0.71	0.89
	(0.107)		(0.255)		(0.141)		(0.092)		(0.83)
Female	-0.94	-0.78	-0.04	-0.02	1.72	0.65	-0.74	-0.69	0.63
	(1.200)		(1.801)		(2.638)		(1.076)		(0.89)

9. ECLC membership co-variates RTS model

Table A4. ECLC membership co-variates RTS model

	Class1 (st. err)	z-value	Class2 (st. err)	z-value	Class3 (st. err)	z-value	Class4 (st. err)	z-value	Wald (p-value)
Intercept	2.26	2.07	-4.75	-1.80	-1.02	-0.67	3.51	3.51	17.80
	(1.093)		(2.645)		(1.518)		(1.001)		(0.000)
Know how schisto is contracted	-0.51	-0.98	-0.13	-0.15	0.88	1.18	-0.24	-0.57	1.65
	(0.524)		(0.865)		(0.749)		(0.415)		(0.65)
Submerged >= 15	-0.59	-1.03	0.41	0.48	0.05	0.08	0.13	0.35	2.67
	(0.575)		(0.852)		(0.620)		(0.389)		(0.44)
Income	-0.14	-2.07	0.15	1.06	0.07	0.64	-0.08	-1.20	4.56
	(0.068)		(0.137)		(0.114)		(0.063)		(0.21)
Female	-0.70	-0.85	2.93	1.37	-0.79	-0.90	-1.44	-1.91	6.40
	(0.824)		(2.136)		(0.883)		(0.752)		(0.094)

10. Mixed Logit Model results (standard deviations)

Table A5. Mixed Logit Model results (standard deviations)

RTS		RTO	
Attribute	Mean (St. err)	Attribute	Mean (St. err)
New water source		**Location**	
Tap 2 jerry cans	-0.816	The Lake	1.67
	(0.261)		(0.266)
Tap 10 jerry cans	-1.373	Market	1.04
	(0.263)		(0.253)
Lake filtration- non-potable	-1.976	5 min from home	-1.21
	(0.359)		(0.174)
Lake filtration- potable	1.862	Maintain	0.61
	(0.316		(0.264)
Landing Sites	-0.190	**Fine issued for defecation**	
		Within 30 m from	
	(0.073)	lake	-0.019
Sensitise			(0.007
Murals	0.007	Everywhere	-1.13
	(0.022)		(0.183)
Public radio	0.087	**None**	-2.91
	(0.186)		(0.311)
VHT talks	0.705		
	(0.256)		
None	2.468		
	(0.266)		

11. Latent Class Models

Table A6. Latent Class log likelihoods for RTS and RTO data, 2-6 classes

	RTS		RTO	
	LL	BIC(LL)	**LL**	**BIC(LL)**
2-Class	-1648.86	3461.136	-1726.17	3591.317
3-Class	-1610.43	3481.104	-1675.89	3575.35
4-Class	-1579.87	3516.82	-1644.93	3598.033
5-Class	-1546.79	3547.493	-1615.44	3623.65
6-Class	-1511.13	3573.007	-1591.94	3661.245

Table A7. 2-Class Latent Class Model, RTS data

	Class 1			Class 2		
	$\hat{\beta}$	$\widehat{WTP}$	$\widehat{WTW}$	$\hat{\beta}$	$\widehat{WTP}$	$\widehat{WTW}$
Attributes	(st. err)	(st. err)	(st. err)	(st. err)	(st. err)	(st. err)
New water source						
Tap 2 jerry cans	0.742	-	13.100	2.471	5,210	-
	(0.201)		(5.750)	(0.485)	(1,054)	
Tap 10 jerry cans	1.400	-	24.711	3.903	8,229	-
	(0.239)		(9.829)	(0.535)	(1,292)	
Lake filtration- non-potable	-0.253	-	-4.463	-1.027	-2,166	-
	(0.207)		(3.936)	(0.570)	(1,203)	
Lake filtration- potable	1.089	-	19.222	1.719	3,624	-
	(0.222)		(7.789)	(0.507)	(1,176)	
Landing Sites						
	0.524	-	9.256	-0.077	-163	-
Sensitise	(0.124)		(3.800)	(0.341)	(722)	
Murals	0.527	-	9.300	0.315	664	-
	(0.122)		(3.879)	(0.342)	(730)	
Public radio	0.985	-	17.387	0.121	256	-
	(0.135)		(6.636)	(0.351)	(744)	
VHT talks	0.174	-	3.067	0.216	455	-
	(0.039)		(1.107)	(0.088)	(212)	
None	-1.940	-	-34.250	1.207	544	-
	(0.432)		(14.310)	(0.630)	(1,420)	
Fee	-0.019			-0.474		
	(0.018)			(0.072)		
Labour	-0.057	-		-0.097	-203	
	(0.020)			(0.078)	(158)	
Class Membership Model						
Intercept	-			-0.612		
				(0.433)		
Know how schisto is contracted	-			-0.054		
				(0.280)		
Submerged >= 15	-			-0.409		
				(0.295)		
Income	-			-0.075		
				(0.039)		
Female	-			0.229		
				(0.297)		
Class Share Size	0.775			0.224		

Table A8. 4-Class Latent Class Model, RTO data

	Class 1			Class 2			Class 3			Class 4		
	$\hat{\beta}$	$\widehat{WTP}$	$\widehat{WTW}$	$\hat{\beta}$	$\widehat{WTP}$	$\widehat{WTW}$	$\hat{\beta}$	$\widehat{WTP}$	$\widehat{WTW}$	$\hat{\beta}$	$\widehat{WTP}$	$\widehat{WTW}$
Attributes	(st. err)	(st. err)	(st. err)	(st. err)	(st. err)	(st. err)	(st. err)	(st. err)	(st. err)	(st. err)	(st. err)	(st. err)
Location												
The Lake	1.422	9,602	-	6.526	-	-	2.638	18,095	-	-0.916	-	-2.954
	(0.308)	(2,757)		(3.678)			(0.478)	(7,393)		(1.216)		(3.324)
Market	1.601	10,810	-	3.676	-	-	1.534	10,524	-	0.299	-	0.965
	(0.274)	(2,426)		(3.351)			(0.49)	(4,801)		(1.053)		(3.577)
5 min from home	2.136	14,419	-	-1.925	-	-	2.714	18,614	-	-0.853	-	-2.750
	(0.257)	(2,708)		(2.389)			(0.455)	(6,838)		(1.134)		(2.977)
Maintain	0.138	936	-	9.451	-	-	0.241	1,654	-	-0.081	-	-0.261
	(0.130)	(906)		(3.555)			(0.246)	(1,659)		(0.457)		(1.465)
Fine issued for defecation												
Within 30 m from lake	0.915	6,179	-	11.514	-	-	1.123	7,706	-	4.386	-	14.132
	(0.210)	(1,886)		(4.632)			(0.316)	(3,611)		(1.569)		(5.010)
Everywhere	0.920	6,211	-	16.766	-	-	1.797	12,323	-	4.015	-	12.938
	(0.197)	(1,773)		(6.452)			(0.349)	(4,805)		(1.213)		(5.035)
None	-0.915	-6,178	-	8.713	-	-	3.638	24,951	-	-1.272	-	-4.099
	(0.488)	(3,270)		(4.602)			(0.570)	(10,312)		(2.023)		(6.187)
Fee (per UGX1,000)	-0.148			-0.255			-0.145			0.170		
	(0.025)			(0.146)			(0.056)			(0.097)		
Labour	-0.039	-266	-	0.760	-		0.059	408		-0.310		
	(0.027)	(175)		(0.328)			(0.060)	(475)		(0.161)		
Class Membership Model												
Intercept	-			-1.605			-0.370			-4.318		
				(0.592)			(0.607)			(1.689)		

Know how schisto is spread =1	-	0.861	0.241	-0.370
		(0.376)	(0.357)	(0.472)
Open defecation = 1	-	0.157	0.647	1.831
		(0.483)	(0.456)	(0.529)
Income	-	0.034	-0.104	0.313
		(0.055)	(0.050)	(0.168)
Female	-	-0.150	-0.543	-1.380
		(0.359)	(0.397)	(1.211)
Class Share Size	0.499	0.211	0.162	0.126

Note: Marginal WTP (WTW) are not calculable for classes where the monthly fee (weekly labour) is insignificant.

References

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