Socio-economic Impact of Remote Sensing Approach to Predict Cholera

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Motivation

- Water scarcity affects more than 40% of the global population, 1.8 billion people globally use fecally contaminated water.
- Approximately 100,000 deaths occur across 69 endemic countries, with an estimated 2.9 million cholera cases every year [Ali et al., 2015].
- Surveillance remains limited, with only about 5%–10% of active cholera cases are estimated to be reported worldwide [WHO, 2017].
- Understanding of cholera in Bangladesh appears limited to two long-term and two temporary surveillance centres (Figure 1). Our target end user International Center for Diarrheal Disease, Bangladesh (ICDDRB) is one of these long standing surveillance systems.
- 66 million people estimated to be at risk of cholera in Bangladesh due to effects of large-scale processes.
- Costs of an episode of cholera estimated at USD$30.40 (BDT৳2356.59) or as high as USD$206 with hospitalization (Poulous, 2012, Sarker, 2013).
- Ongoing vaccination programs place the household burden at USD$3.98 per vaccine, which is 58% of the overall cost of the vaccination (Sarker, 2015).

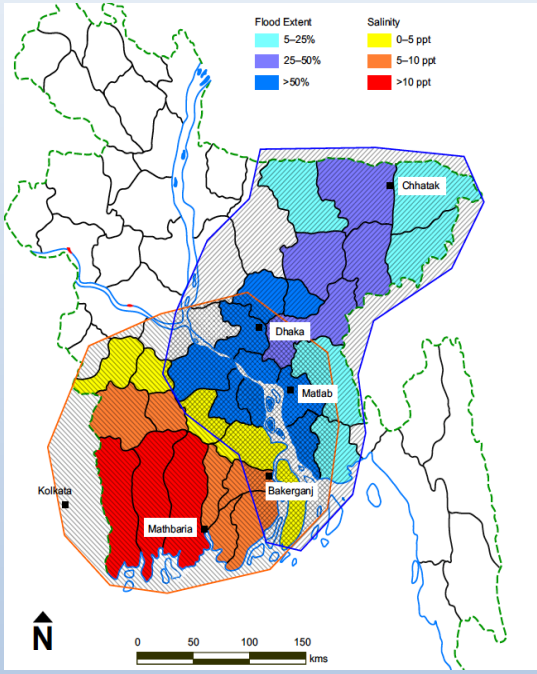

Figure 1: Population Vulnerability to conditions favorable to biannual cholera outbreaks
[Akanda et al. AJTMH 2013]

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Goal of Project

- Economic valuation of a cholera prediction system using earth observations.
  - Estimate damages averted
  - Goal of primary data analyses focuses on estimates of household behavioral aspects of cholera avoidance.
  - Optimize value of early warning system
    - Provide data to support decision making criteria to maximize use-ability/benefit of cholera prediction system.
  - Optimize decision making for sustained use of earth observations for the ultimate end user – the at risk population.

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Integration of Prediction Framework with Economic Model

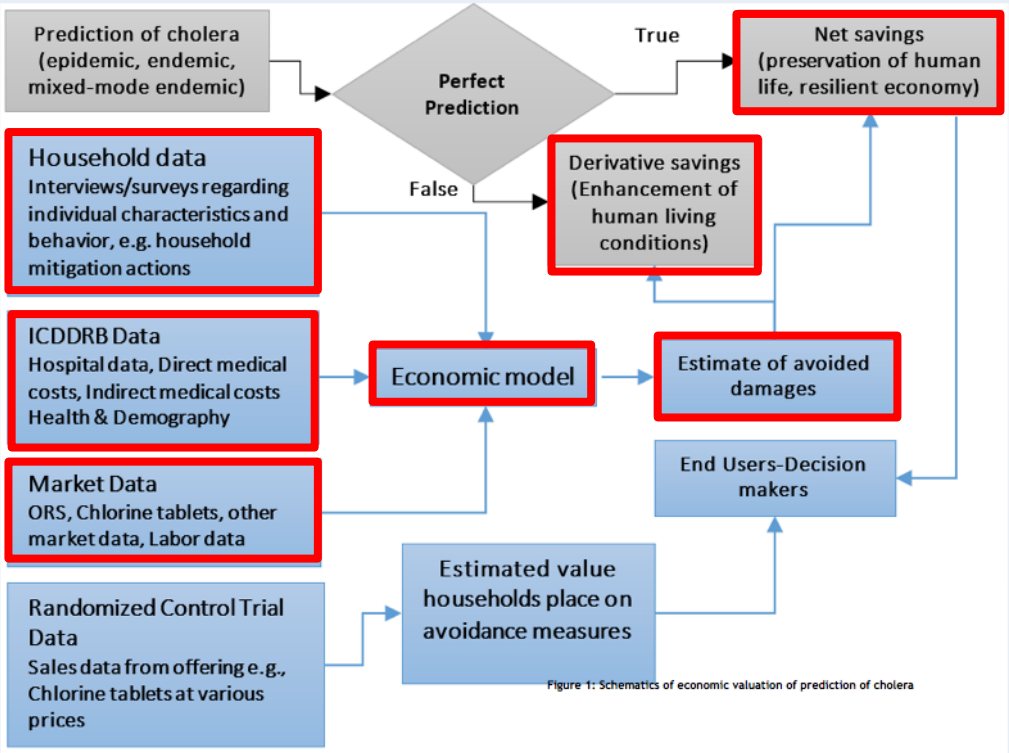

Figure 1: Schematics of economic valuation of prediction of cholera

Data Sources
-Household
-ICDDRB*
-Market

Economic Model
- Model optimized household decision making to avert cholera (proxy measure used: willingness to pay (WTP) for Cholera Vaccine)

Estimate of avoided damages

Estimate of improved social benefit from satellite predictions

Informs Decision Making
- Public Health Policy Makers
- Public

*ICDDRB - International Center for Diarrheal Disease Research in Bangladesh

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Field Data Collection

Primary Data: Two thirds of target sample household survey size complete.

- Elicitation of willingness to mitigate cholera:
  - Elicit willingness to pay (WTP) to avert cholera.
  - Observe current mitigation practices.
  - Investigate factors that affect household choices or WTP to avert cholera.

Primary Data: ICDDRB end user preferences elicited on mobilizing ground resources

- •Preferences indicate applicability of NASA's satellite data on advance warning systems, intervention methods and dissemination.

Secondary data acquisition:

- •Completed ICDDR,B Research Review Committee approval to obtain secondary cost of illness/patient data in collaboration with ICDDR,B clinical and hospital services.

Results

- Empirical models results indicate Initial findings are validated, and subject to further validation with third round of collection.

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Results

Dependent Variable: Vaccine WTP		Vaccine WTP for Child
Independent Variable	Coefficient	Coefficient
Vaccine Awareness	-10.601 (4.619)**	-8.882 (4.782)*
Past Household Cholera	-7.135 (3.894)*	-6.575 (4.032)
Household Diarrhea	9.075 (5.04)*	7.908 (5.218)
Water Safety	4.026 (3.991)	2.915 (4.132)
Children Under 5	6.98 (4.535)	10.357 (4.695)
Income	9.326 (1.763)***	9.746 (1.825)***
Number of members in household	-6.911 (1.883)***	-7.950 (1.95)***
Objective Total Knowledge Index		
Objective Cause Knowledge Index	6.061 (4.931)	6.002 (5.105)
Objective Symptom Knowledge Index	3.584 (5.465)	3.753 (5.658)
Objective Prevention Knowledge Index	17.880 (4.992)***	23.010 (5.168)***
Subjective Total Knowledge Index		
Subjective Cause Knowledge Index	-2.53 (4.746)	-3.841 (4.914)
Subjective Symptom Knowledge Index	-1.967 (4.882)	-1.012 (5.054)
Subjective Prevention Knowledge Index	-8.143 (4.673)*	-12.986 (4.838)***
*, **, *** denote significance at the 10%, 5%, and 1% significance levels, respectively. Standard errors appear in parentheses. N=1093		

Table 1. Indicators of Household Willingness to Pay for Vaccination in the Mirpur area of Dhaka, Based on Reported WTP, With and Without Advance Warning System, *n =1014*

	Willingness to Pay for Vaccine (w/o AWS)		Willingness to Pay for Vaccine (w/ AWS)	
	WTP for Vaccine	WTP for Child's Vaccine	WTP for Vaccine with AWS	WTP for Child's Vaccine with AWS
Education	0.14**	0.13***	0.23***	0.22***
	(0.06)	(0.06)	(0.06)	(0.09)
Income	0.27***	0.30**	0.31***	0.31***
	(0.06)	(0.06)	(0.08)	(0.08)
Number of HH Members	-0.13***	-0.14**	-0.17***	-0.17***
	(0.04)	(0.04)	(0.05)	(0.05)
Willingness to Seek Treatment	0.22*	0.22*	0.27*	0.26*
	(0.11)	(0.12)	(0.14)	(0.15)
Smartphone Ownership	0.29**	0.32***	0.38**	0.40**
	(0.12)	(0.13)	(0.15)	(0.16)
Watersafety	0.12	0.19	0.15	0.14
	(0.12)	(0.13)	(0.15)	(0.18)
(Constant)	0.82***	0.79***	0.94***	1.02***
	(0.24)	(0.25)	(0.3)	(0.31)

Confidence level markers: *:90%, **:95%, ***:99%

Numbers in parentheses are standard errors

With the suggestion of an early warning system for outbreaks, average WTP increases by ~ 19% for respondents' own vaccination, and ~17% for vaccination for their child.

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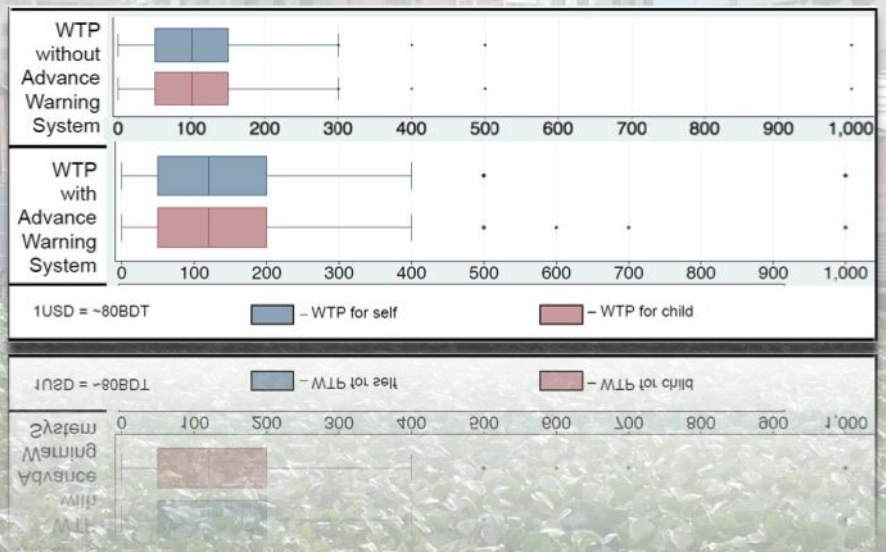
Averting Behavior Before & After Advance Warning



Highlights:

Respondents show an increase in WTP for cholera averting measures given a publicly available cholera outbreak early warning system (EWS).

Coefficient estimates suggest that WTP increases in magnitude given advanced warning.

An advanced warning system increases the willingness to engage in cholera averting behavior across the population.

An advanced warning system, subject to effective messaging, provides direct benefits to the at risk population from development of satellite prediction products.

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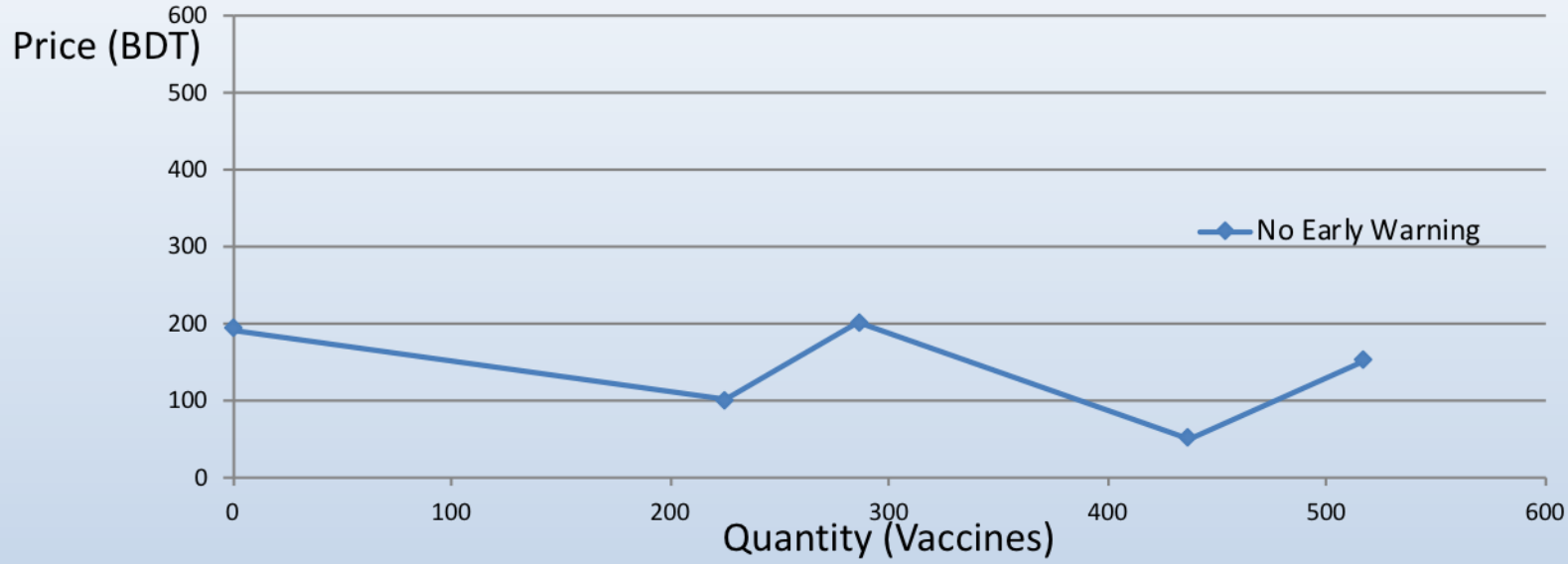
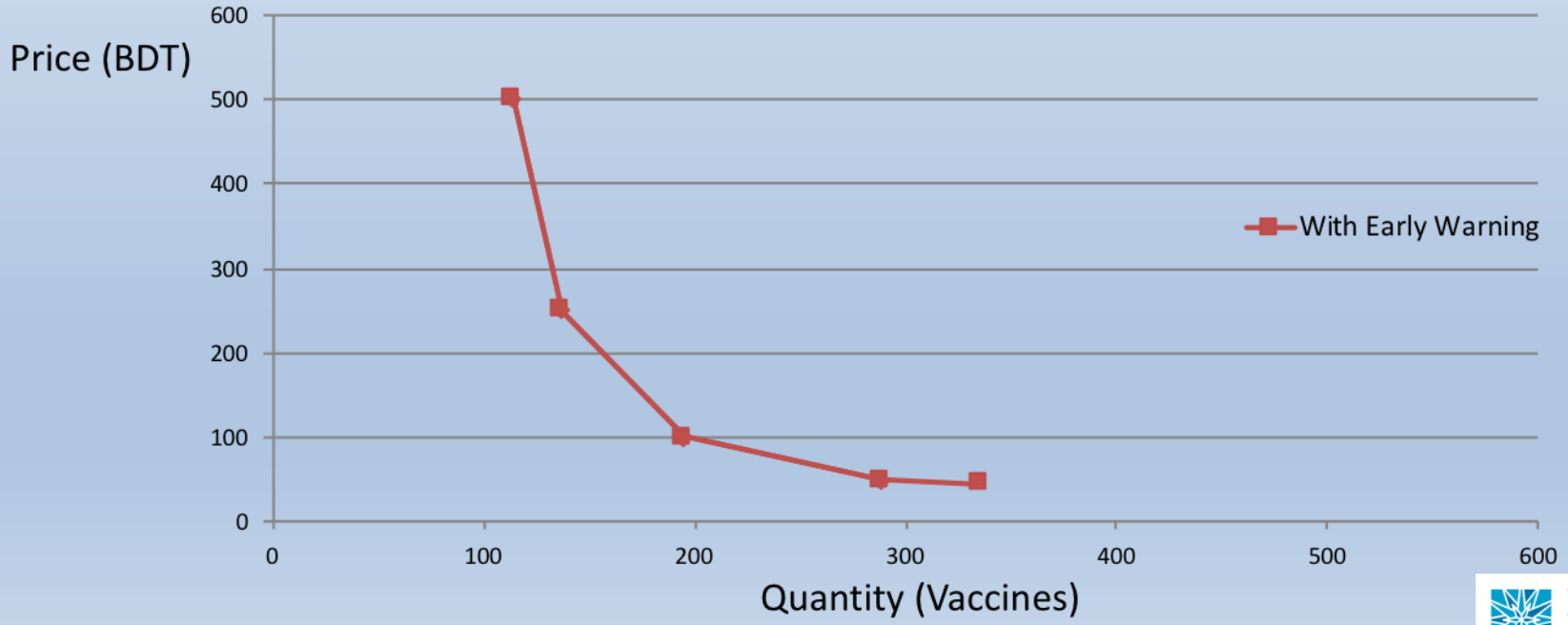
Demand/WTP for Averting Cholera





All prices quoted in local bangladeshi taka (BDT), US$1=BDT ৳79.3 at 2016 exchange rate

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Ongoing & Planned Work

- Complete primary data collection (October-December, 2018)
- Secure and integrate the ICDDRB health data with primary data collected (October, 2018).
- Expected outcomes
  - Estimate private value of household protection against cholera, with and without EWS.
  - Estimate public value of population protection against cholera, with and without EWS.
  - Estimate demand elasticity parameter
  - Set framework to craft messaging and signaling strategies to maximize use of NASA's satellite based early warning system by at risk population (Ongoing and future work).
- Future work
  - End user (ICDDR, B) disseminates targeted intervention with our parameter in hand.
  - Use demand elasticity to inform sustained use of EWS, and to inform public health mitigation (and public health product pricing policies)
  - Use data in hand to estimate parameters focused on integration of estimated parameter with the at risk population.
    - Develop stochastic model of averting behavior.
    - Optimize messaging and signaling strategies to maximize social well being of at risk population.

Challenges to Implementation

Secondary data set not yet secured due to institutional delay, however we are told it will be in hand mid October, 2018. This allows an accounting measure of the dollar value per case of cholera averted.

Third round of primary data not yet secured (Targeted completion was August, 2018)

Barriers to implementation

- Ease of access to study areas
- Ease of access to at risk population (whether to knowledge or mitigation technology)

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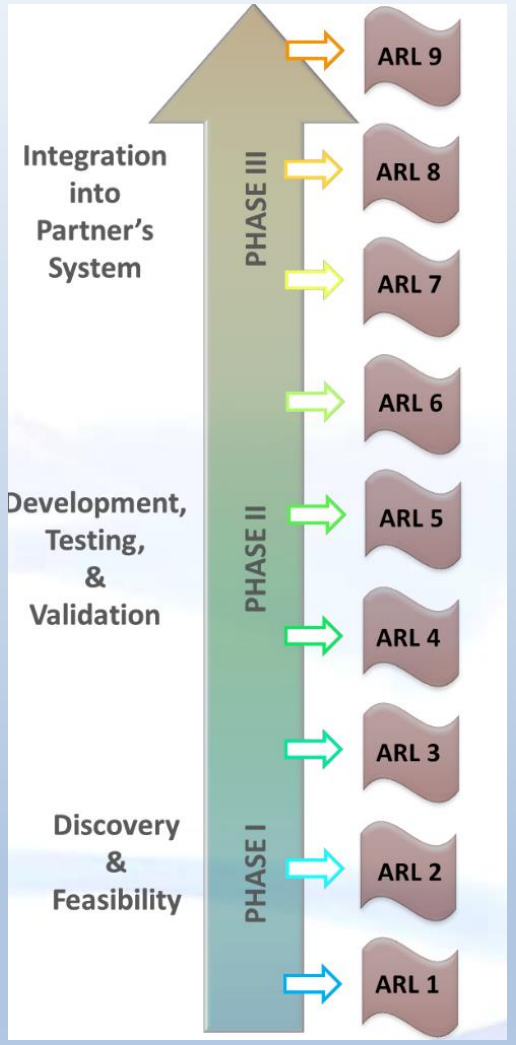
ARL Target

ARL

Current: 7

Expected to achieve: 8



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Welfare measure

$$\frac{-\frac{\partial W}{\partial r_c}}{-\frac{\partial W}{\partial r_m}} = \frac{\psi_{r_c}}{\psi_{r_m}} = \frac{\left[\gamma_{r_c}{}^{\pi} + \gamma_{r_c}{}^{G} + \gamma_{r_c}{}^{c} + \gamma_{r_c}{}^{m}\right]}{\left[\gamma_{r_m}{}^{\pi} + \gamma_{r_m}{}^{G} + \gamma_{r_m}{}^{c} + \gamma_{r_m}{}^{m}\right]}$$

Observations

- EWS may affect elasticity
- Knowing elasticity will help with building EWS
  - » *Customize strategies to optimize at risk population's uptake of averting measures.*

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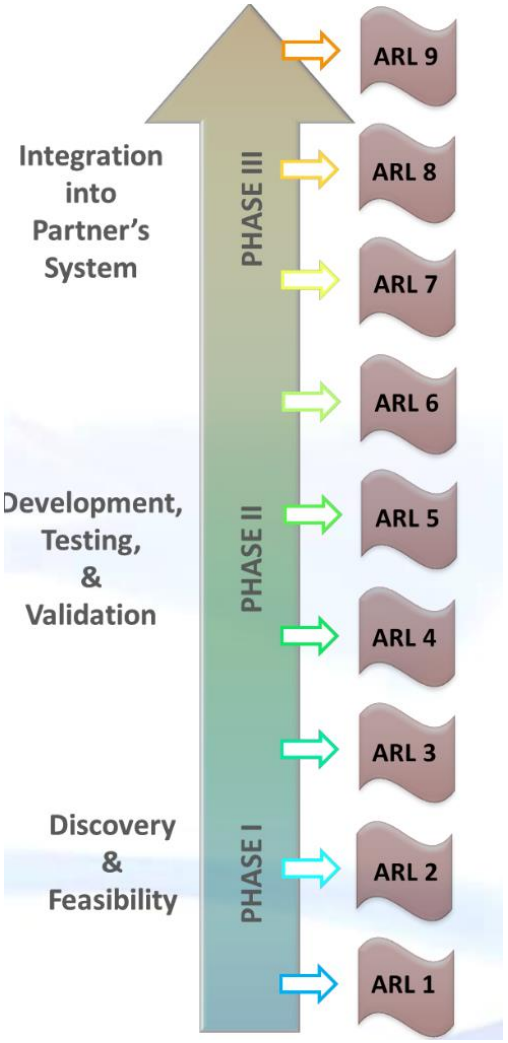
ARL Target

ARL:

- Beginning – 2/3
- Current – ARL 5/6
- Target ARL 8



Results Continued..

	WTP for Vaccine with EWS					WTP for Child's Vaccine with EWS				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Education	0.28***	0.29***	0.26***	0.26***	0.34***	0.28***	0.29***	0.26***	0.25***	0.33***
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.08)	(0.08)	(0.07)
Housewife	-0.37**	-0.35**	-0.38**	-0.37**	-0.34**	-0.31*	-0.30*	-0.31*	-0.31*	-0.28
	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)	(0.18)	(0.18)	(0.18)	(0.18)	(0.18)
Income	0.36***	0.35***	0.34***	0.33***		0.36***	0.36***	0.34***	0.32***	
	(0.07)	(0.08)	(0.07)	(0.07)		(0.08)	(0.08)	(0.08)	(0.07)	
HHMembers	-0.15***	-0.16***	-0.16***	-0.16***	-0.12***	-0.16***	-0.16***	-0.16***	-0.16***	-0.13***
	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
CTCclinictotal	0.25*	0.25*	0.25*	0.24*	0.19	0.24	0.24	0.24*	0.23	0.19
	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.15)	(0.15)	(0.15)	(0.15)	(0.15)
Age		0.004					0.0019			
		(0.007)					(0.007)			
Watersafety			0.19					0.18		
			(0.15)					(0.15)		
Smartphone				0.35**	0.48***				0.39**	0.51***
				(0.15)	(0.15)				(0.16)	(0.15)
(Constant)	1.09***	0.97***	1.10***	1.14***	1.68***	1.12***	1.07***	1.14***	1.18***	1.71***
	(0.31)	(0.36)	(0.31)	(0.31)	(0.29)	(0.32)	(0.38)	(0.32)	(0.32)	(0.30)

Confidence level markers: * : 90%, ** : 95%, *** : 99%
Standard errors in parentheses