Environmental and Development Economics
Module 4 - WTP for Environmental Quality in LMICs

Raahil Madhok
UMN Applied Economics

2024-09-26

Lecture 6

WTP Estimation: Revealed Preference Models

Housekeeping

- Research Proposal: you do NOT have to carry out analysis
- First draft: Oct 3rd
- Replication: Oct 21st
  - Start soon

Today

- **Guiding question:** what is the WTP for environmental quality in LMICs?

- Today's focus: How do we even measure this?
  - Behavioral models
  - Choice probabilities
  - Estimation
  - Application to WTP

- Next time: why is WTP so low in developing countries?

Estimating Non-market Value of Goods and Services

- **Stated Preference:**
  - Hypothetical data to estimate **ex-ante** WTP
  - Contingent valuation, contingent behavior
  - Respondents directly asked about WTP (phone, mail, etc.)
  - Issue: hypothetical bias and strategic bias
- **Revealed preferences**
  - Behavioral data to estimate **ex-post** WTP
  - Travel cost, averting behavior, hedonic price
  - Pro: based on **actual** choices
  - Con (?): need a **behavioral model** in which to analyze choices

Behavioral Models

- Our goal is to define a behavioral process generating agent's choice
- Let agent face choice among set of options (products, actions, etc.)
  - What leads agent to choose one?
- Let some factors (x) be observed by researcher, and some not (ϵ)
- Factors relate to agent choice through a **behavioral process**:

$$y = h(x, \epsilon)$$

- $h(x, \epsilon)$ determines the selected choice based on these factors

Probabilistic Choice

- Since ϵ unobserved, the outcome is probabilistic
- **Choice probability** of choosing y derived by assuming $\epsilon \sim f(\epsilon)$

$$P(y|x) = \text{Prob}(\epsilon \quad \text{s.t.} \quad h(x,\epsilon) = y)$$

- This probability is much more tractable i.e., fully characterized by $f(\epsilon)$
- We can rewrite this as the expected value of an indicator function:

$$P(y|x) = \int I[h(x,\epsilon) = y] f(\epsilon) d\epsilon$$

- where $I[h(x,\epsilon) = y] = 1$ when statement in brackets is true
- Integral of behavioral process indicator over all possible values of unobservables

Evaluating the Choice Probability

- Method 1: Closed-form solution
  - For certain specifications of h and f, $P(y|x)$ calculated via a formula
  - Main example is Logit

- Method 2: Simulation
  - Some specifications of h and f have no closed form solution
  - We simulate $P(y|x)$ by taking random draws from f and taking the average

Evaluating the Choice Probability: Closed Form

First, define the behavioral model

- Consider a binary model where agent considers whether to take an action
- Agent gets utility (+/-) from the action:

$$U = \beta' x + \epsilon$$

- U: Utility of taking an action; $\beta' x$: Observed component of utility.
- ϵ: Unobserved component; lets assume **logistic distribution**.
- Take action if utility is positive:

$$P = \int I[\beta' x + \epsilon > 0] f(\epsilon) d\epsilon$$

Closed Form Solution

$$
\begin{aligned}
P &= \int I[\beta' x + \epsilon > 0] f(\epsilon) d\epsilon \\
&= \int_{\epsilon > -\beta' x} f(\epsilon) d\epsilon \\
&= 1 - F(-\beta' x) \\
&= 1 - \frac{1}{1 + e^{\beta' x}} \\
&= \frac{e^{\beta' x}}{1 + e^{\beta' x}}
\end{aligned}
$$

Evaluating the Choice Probability: Simulation

Recall: $P(y|x) = \int I[h(x,\epsilon) = y]f(\epsilon)d\epsilon$

- **Step 1:** Take draw of ϵ from $f(\epsilon)$
  - Label it ϵ^1, denoting first draw
- **Step 2:** Check whether $h(x, \epsilon^1) = y$
  - If so, create $I^1 = 1$, otherwise $I^1 = 0$
- **Step 3:** Repeat this R times and collect I^r for $r = 1, ..., R$
- **Step 4:** Average **simulated** probability: $P(i|x) = \frac{1}{R}\sum_{r=1}^{R} I^r$
  - Proportion of times that draws of ϵ, when combined with x, yield y

Lets define a realistic behavioural model

Grounded in economic theory

Random Utility Model

Behavioural model:

- Agent, n faces choice among J alternatives
  - Choice set must be 1) mutually exclusive, 2) exhaustive, 3) finite
- Utility from j is: U_{nj} for $j = 1, ..., J$
- Utility known to agent but not the researcher
- Agent chooses j that maximizes utility:

$$\text{Choose i iff} \quad U_{ni} > U_{nj} \quad \forall j \neq i$$

Random Utility Model

The Researcher

- Observes attributes of alternatives, $x_{nj} \quad \forall j$
- Observed attributes of agent, s_n
- Let $V_{nj} = V(x_{nj}, s_n) \quad \forall j$ (representative utility)
- **V can depend on parameters unknown to researcher**
  - But can be structurally estimated...

Random Utility Model

- Since $V_{nj} \neq U_{nj}$, we can write:

$$U_{nj} = V_{nj} + \epsilon_{nj}$$

  - where joint density of random vector $\epsilon_n = (\epsilon_{n1}, ..., \epsilon_{nJ}) = f(\epsilon_n)$
- Then the probability than agent n chooses alternative i is:

$$\begin{aligned} P_{ni} &= P(U_{ni} > U_{nj}, \forall j \neq i) \\ &= P(V_{ni} + \epsilon_{ni} > V_{nj} + \epsilon_{nj}, \forall j \neq i) \\ &= P(\epsilon_{nj} - \epsilon_{ni} < V_{ni} - V_{nj}, \forall j \neq i) \leftarrow \text{CDF!} \\ &= \int I(\epsilon_{nj} - \epsilon_{ni} < V_{ni} - V_{nj}) f(\epsilon) d\epsilon \end{aligned}$$

- Different DCMs obtained from different choices of $f(\epsilon)$

Logit

- Assumes ϵ_{nj} distributed iid extreme value

$$\text{PDF:} \quad f(\epsilon_{nj}) = e^{-\epsilon_{nj}} e^{-e^{-\epsilon_{nj}}}, \quad \text{CDF:} \quad F(\epsilon_{nj}) = 1 - e^{-e^{\epsilon_{nj}}}$$

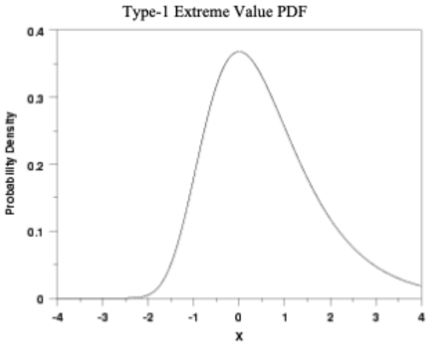
- Note: if ϵ's are iid EV, then $\epsilon^*_{nji} = \epsilon_{nj} - \epsilon_{ni}$ is distributed logistic:

$$F(\epsilon^*_{nji}) = \frac{e^{\epsilon^*_{nji}}}{1 + \epsilon^*_{nji}}$$

Aside: Extreme Value Distribution

Useful Properties

1. Mathematical tractability
   - Closed form choice probability
2. Long right tail
   - Unobservables can drive unexpected choices
3. IIA property
4. Connection to logistic regression
5. Easy to (structurally) estimate



Logit

- The probability that agent n chooses alternative i:

$$\begin{aligned}
P_{ni} &= P(V_{ni} + \epsilon_{ni} > V_{nj} + \epsilon_{nj} \quad \forall j \neq i) \\
&= P(\epsilon_{nj} < \epsilon_{ni} + V_{ni} - V_{nj} \quad \forall j \neq i) \leftarrow \text{invoke iid assumption!} \\
&= \int \left(\prod_{j \neq i} e^{-e^{-(\epsilon_{ni} + V_{ni} - V_{nj})}} \right) e^{-\epsilon_{ni}} e^{-e^{-\epsilon_{ni}}} \, d\epsilon_{ni} \\
&= \frac{e^{V_{ni}}}{\sum_j e^{V_{nj}}}
\end{aligned}$$

- **Preview:** If V is linear in parameters, $V_{nj} = \beta' x_{nj}$, then: $P_{ni} = \frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}}$

Independence of Irrelevant Alternatives

- Crucial assumption in logit model
- Relative odds of choosing b/w 2 i and k does not change when j introduced
- For any two alternatives i and k, the ratio of logit probabilities is:

$$\frac{P_{ni}}{P_{nk}} = \frac{e^{V_{ni}} / \sum_j e^{V_{nj}}}{e^{V_{nk}} / \sum_j e^{V_{nj}}} = \frac{e^{V_{ni}}}{e^{V_{nk}}} = e^{V_{ni} - V_{nk}}$$

- Ratio does not depend on any alternatives other than i and k!
  - Denominators cancel

Discussion of IIA Assumption

- Advantages
- Disadvantages

5 minute break

Estimation: Maximum Likelihood Structural Estimation

- Suppose we have have data on N agent's choices
- The likelihood of observing the choices made by each individual is:

$$L(\beta) = \prod_{n=1}^{N} \prod_{i} (P_{ni})^{y_{ni}}$$

- where $y_{ni} = 1$ if alternative i is chosen, and 0 otherwise
- Log-likelihood is easier to maximize:

$$LL(\beta) = \sum_{n=1}^{N} \sum_{i} y_{ni} \log(P_{ni})$$

- ML estimator is the β that maximizes this function

Method of Moments

- FOC of $LL(\beta) \leftrightarrow \frac{\partial LL(\beta)}{\partial \beta} = 0$
- This can be rewritten as:

$$\frac{1}{N}\sum_{n=1}^{N}\sum_{i} y_{ni}x_{ni} = \frac{1}{N}\sum_{n=1}^{N}\sum_{i} P_{ni}x_{ni}$$

- LHS: mean x over choices by sampled agents
- RHS: mean x over **predicted** choices by sampled agents
- β found s.t. predicted mean of each explanatory variable equals observed mean
  - Model reproduces observed averages in the data
  - Also known as **matching on the first moment**

Limitations

- Cannot represent random taste variation
- Implies proportional substitution across alternatives (IIA)

What if we want to estimate more moments of β?

Specifying Taste Variation

- Supposed agent now has the utility: $U_{nj} = \beta_n{}' x_{nj} + \epsilon_{nj}$
  - where $\beta_n \sim f_n(\beta|\Theta)$ and ϵ_{nj} still iid EV
- If we observed β_n, then we are back to logit: $P_{ni}(\beta_n) = \frac{e^{\beta_n' x_{ni}}}{\sum_j e^{\beta_n' x_{nj}}}$
- Instead, we integrate logit over all possible parameters of β_n:

$$P_{ni} = \int \underbrace{\left(\frac{e^{\beta_n' x_{ni}}}{\sum_j e^{\beta_n' x_{nj}}} \right)}_{\text{logit probability}} \underbrace{f(\beta|\Theta) d(\beta)}_{\text{mixing distribution}} \quad \leftarrow \text{no closed form solution!}$$

- Mixing distribution usually normal: $f(\beta|\Theta) = f(\beta|\mu, \sigma)$
- Note: P_{ni} is a function of Θ, not β! (β is integrated out)

Aside: Properties of Mixed Logit

- Relaxes IIA assumption!
- Ratio of mixed logit probabilities, P_{ni}/P_{nj} depends on all data
  - Denominators are inside the integral and do not cancel
- Enables correlation in unobserved factors across alternatives
  - Flexible substitution patterns

Estimation: Simulation

Steps for Simulating Mixed Logit Probability

1. Draw a value β^r from $f(\beta|\Theta)$, where r is which draw
2. Calculate the logit formula $P_{ni}(\beta^r)$ using the drawn value
3. Repeat steps 1 and 2 for R draws.
4. Average the results to obtain the simulated probability:

$$\hat{P}_{ni} = \frac{1}{R} \sum_{r=1}^{R} P_{ni}(\beta^r)$$

Simulated Log-Likelihood Estimation

- As before, insert simulated $\hat{P}_{ni}$ into log-likelihood:

$$SLL = \sum_{n=1}^{N} \sum_{j=1}^{J} y_{nj} \ln \hat{P}_{ni}$$

- where $y_{nj} = 1$ if n chose j and zero otherwise
- Maximum simulated likelihood estimator (MSLE) is the Θ that maximizes SLL

This recovers taste distribution (μ, σ) that matches observed choices to predicted choice probabilities as close as possible

Lets do a simple application

What is the WTP for biodiversity?

WTP for Species Diversity in India

- **Context:** people travel to "hotspots" to see pretty birds
  - Birds are a good proxy for overall biodiversity
- **Data:** individual level data from citizen science app (eBird)
  - location, alternative sites, income, **travel cost**, **species richness**
- **Behavioral model:** choose site that maximizes utility
- **Question:** what cost will you incur to $\uparrow$ utility from biodiversity?
  - How does your "price" change for an additional unit of biodiversity? (MWTP)

Deriving WTP in Practice

- Agent i's utility from site j at time t is:

$$\begin{aligned} U_{ijt} &= V_{ijt} + \epsilon_{ijt} \\ &= \underbrace{\beta_1}_{\text{MU Income}} (y_i - c_{ijt}) + \underbrace{(\beta_2 + \eta_i)}_{\text{MU EQ}} e_{jt} + \ldots + \epsilon_{ijt} \end{aligned}$$

- If stay home: $U_{i0t} = \beta_1 y_i + \epsilon_{i0t}$
- Cost s.t. i indifferent b/w travelling and avoiding cost:

$$c_{ijt}* = \frac{1}{\beta_1}[(\beta_2 + \eta_i)e_{jt} + \beta_3 x_{ijt} + \ldots + (\epsilon_{ijt} - \epsilon_{i0t})]$$

- MWTP for one more species, assuming $\eta_i \sim N(0, \sigma)$:

$$MWTP = \boxed{\frac{\partial c_{ijt}*}{\partial d_{jt}} = \frac{\hat{\beta}_2}{\hat{\beta}_1} + \cancel{\frac{\hat{\eta}_i}{\hat{\beta}_1}}}$$

Implementation

- Data
  - attributes of choice and alternatives for each **choice occasion**
  - Variable *choice=1* if chosen, otherwise 0
  - Data can get huge, and simulation takes forever
  - solution: restrict choice set
- Stata
  - clogit: conditional logit (fast)
  - mixlogit: mixed logit estimation (slow)
- R
  - *mlogit* library
  - Exercises and applications: https://cran.r-project.org/web/packages/mlogit/vignettes/c5.mxl.html

Aside

- **If you want to get involved in this project, let me know**
- Goal: estimate WTP for species diversity in India

Lecture 7

Why is WTP for Environmental Quality Low in Developing Countries?

Housekeeping

- Free lecture (Oct 10)
  - Choose one: 1) firms, 2) migration, 3) policy (guest lecture)
- Research Proposal: first draft due one week from Thursday
- All assignments have detailed instructions and rubric
- Start selecting replication paper

WTP for Environment Quality in LMICs

- Crucial for policy design (Greenstone and Jack, 2013)
- Most papers estimate $MWTP_s$
  - and assume market failures do not bias valuation
- Examples of $MWTP_s$
  - MWTP for water filter in Ghana: $1.80-2.40 (Berry et al. 2011)
  - MWTP for clean cookstoves in Kenya: $12 (Berkouwer and Dean, 2022)
  - MWTP for sanitation in Cambodia: $30 (Ben-Yishay et al., 2017)
- Revealed Preferences: very few!
  - WTP for clean water: Kremer et al. (2011) ← *today*
  - WTP for clean air: Ito and Zhang (2020)
  - WTP for biodiversity: ???

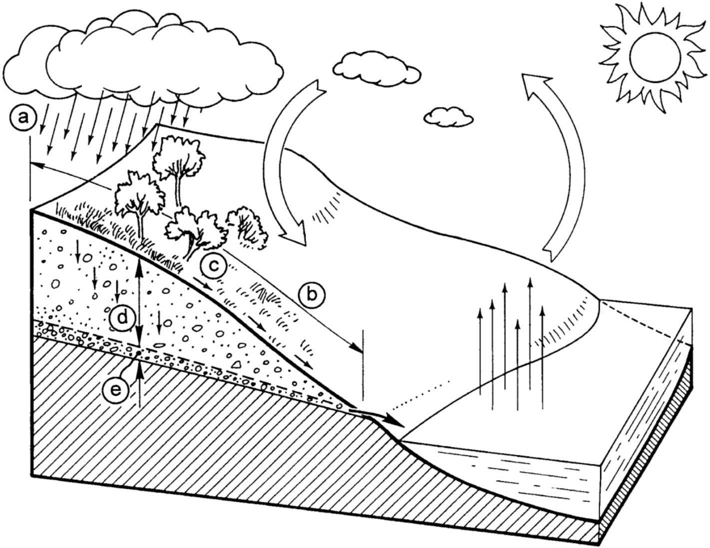
Kremer et al. (2011): WTP for Clean Water in Kenya

- **Research Question:** What is household WTP for clean water in LICs?
  - What are health impacts of water quality improvements?
- **Setting:** 1,354 households in Kenya
- **Intervention:** Improve water quality at source for 184 natural springs
- **Empirical Strategy:** RCT + Revealed preference valuation
- **Results:** Clean water valued at $USD 2.96 per hh ($800 VSL)

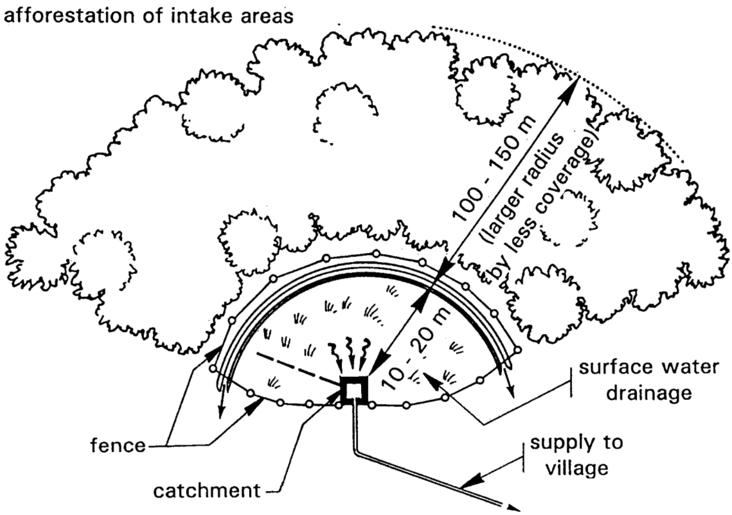
Spring Protection

- Spring water is crucial drinking water source in Africa
  - But vulnerable to contamination when people dip vessels
  - Runoff introduces animal/human waste
- Spring protection common in Africa to improve water quality at source
- Seal off spring at source by encasing in concrete
  - Water flows out of pipe rather than ground, avoiding contamination
- Nothing can "break" $\rightarrow$ less maintenance than wells/pumps
- How much are hh WTP for spring protection?

Spring Protection



Spring Protection



Spring Protection

Spring Protection

Figure 1: Source: USAID

Study Sample

- Sample frame: list of all unprotected springs in Busia and Butere-Mumias districts
- Treatment: 184 randomly selected for protection
  - 1,345 households selected that use springs
- 7-8 households from each spring select from "user list''
- Phased design: all springs eventually protected
  - Round I (Jan-Apr 2005); 47 springs, 350 households
  - Round II (Apr-Nov 2005); 46 springs; 349 households
  - Round III (2005-2006); 91 springs; 685 households

Data Collection

- Water quality measured at each spring based on EPA protocols
  - Measure: E.Coli (log of # bacteria per 100ml)

- Household survey
  - Diarrhea
  - Anthopometrics
  - Water collection behvavior
  - Socioeconomic data

- No difference in baseline water quality between treatment/control springs

Water Quality and Health

- Impact of spring protection on water quality:

$$W_{jt'}^{SP} = \alpha_t + \phi_1 T_{jt} + X_j^{SP'} \phi_2 + (T_{jt} \cdot X_j^{SP})' \phi_3 + \epsilon_{jt}$$

  - where W_{jt} is water quality for spring j at time $t \in 0, 1, 2, 3$
  - T_{jt} is treatment status (=1 after protection)
  - ϕ = impact of spring protection on water quality

- Impact on health

$$Y_{ijt} = \alpha_i + \alpha_t + \phi_1 T_{jt} + X_{ij}' \phi_2 + (T_{jt} \cdot X_{ij})' \phi_3 + u_{ij} + \epsilon_{ijt}$$

  - where Y_{ijt} is whether child i had diarrhea in the past week

Results: Impact of Spring Protection on Water Quality and Health

Water Quality

- Huge improvement in water quality: 66% $\downarrow$ in E.coli
- No heterogeneity by baseline hygiene knowledge or education
  - Hypothesis: educated hh may maintain spring better
- Improvement in home water quality: 24% $\downarrow$ in E.coli
  - Why is the effect smaller?

Health

- Diarrhea incidence $\downarrow$ by 4.7pp (20% reduction compared to control)
- No impact on child weight
- Positive effect on BMI

What if control households choose to use treatment springs?

Revealed Preference: Valuing Clean Water in Kenya

- Let valuation of water from source j be Z_j
  - reflects health and non-health attributes (e.g. ease of collection)

- β_i: indirect utility from protection (T_{jt}) at j at time t

- $C_i > 0$ is time cost per minute of household i

- $C_i D_{ij}$: Travel cost for additional trip to j where D_i is round-trip distance

- Each trip affected by unobserved factors (weather, queue, errands, mood)

Revealed Preference Approach

- Household indirect utility from one trip to j at time t is:

$$u_{ijt} = \beta_i T_{jt} + Z_j - C_i D_{ij} + e_{ijt}$$

  - where e_{ijt} is iid type I extreme value distributed

- i chooses j over k if:

$$\beta_i(T_{jt} - T_{kt}) + (Z_j - Z_k) - C_i(D_{ij} - D_{ik}) + (e_{ijt} - e_{ikt}) \geq 0$$

- Using CDF of EV Type I error, prob. of choosing j over alternatives h:

$$P(y_{ijt}|X) = \frac{exp(X'_{ijt}\beta)}{\sum_h exp(X'_{iht}\beta)} \equiv \rho_{ijt}$$

Mixed Logit

- Add preference heterogeneity with mixed logit:

$$P(y_{ijt}|X) = \int_{\beta} \rho_{ijt} f(\beta) d\beta$$

  - where $f(\cdot)$ is the mixing distribution
- Maximize SLL to estimate mean and s.d. of these distributions
- **What is the object of interest?**

WTP results

- Conditional logit estimates: how do we interpret these?
  - Coefficient on walking distance ($C_i D_{ij}$) = -0.055
  - Coefficient on spring protection (β_i) = 0.51

- **Can β_i entangle other amenity values?**

- Coeff. on (T_{jt} $\times$ under-3 child) is positive (insignificant)
  - Households with kids value water quality more

WTP for spring protection

- Ratio of **mixed logit** coefficients: 2.95/0.21=14 minutes
- Households value clean water by willing to walk 14 extra minutes
- Average hh takes 48 trips per week (see Descriptive Stats)
- Total extra minutes per year = 14 x 48 x 52 = 35,078 minutes
- Assuming 8-hour workday $\rightarrow$ **mean value of clean water is 73 workdays**
  - Note: in paper, it is 32.4 workdays!

Converting WTP to dollars

Survey evidence

- Subset of 104 respondents
- Contingent valuation: are you WTP \$5 to walk 1 less minute? \$10?, etc
- Divide WTP (in terms of time) by money value of time
- Regress time value on household characteristics, and predict on full sample
- Mean value of time = \$USD 0.088 for 8-hr workday

Wages

- \$USD 1.26 for 8-hour day (Suri, 2009)
- Time cost = 25% of average workday wage

Comparison with Contingent Valuation

- Households in protected spring communities asked:
  - **How much are you WTP per year to keep the spring protected?**

- In follow up survey:
  - First: are you willing to pay 500 shillings ($7.14)?
  - Second: are you willing to pay 1000 shillings ($14.29)?
  - Then emphasize tradeoff (opportunity cost) and ask again

- Almost all WTP $7.14
  - Majority WTP $14.29 even after learning about tradeoff
  - Starting value matters!

Health Valuation and VSL

- Spring protection averts **3.2 diarrhea cases per household-year**
  - (0.047 cases/child-week) * (1.3 children under 3 per hh) * (52 weeks/year)

- Annual WTP for spring protection $=$ 32.4 workdays/year
  - Assume this value captures benefits from averted diarrhea

- If protection prevents 3.2 cases/yr, valued at 32.4 workdays/yr, then

$$\text{WTP/case averted} = \frac{\text{Total Workdays}}{\text{Diarrhea Cases Averted}} = \frac{\text{32.4 workdays}}{\text{3.2 cases}} = \text{10.1 workdays/case}$$

Health Valuation and VSL

- Assume spring protection $\downarrow$ diarrhea morbidity & mortality proportionally
- Using fact that 862 diarrhea cases $\rightarrow$ 1 death (literature):
- WTP to prevent 862 diarrhea cases (1 death) i.e. VSL:

$$\text{Total WTP/death averted} = 10.1 \text{ workdays} \times 862 \text{ cases} \approx 8{,}700 \text{ workdays}$$

VSL = \$0.088 $\times$ 8700 $\approx$ \$USD 770

In USA 2013: VSL $\approx$ \$USD 8.5 million (EPA)

Discussion

- What do you think about approach?
- What do you think about time valuation?

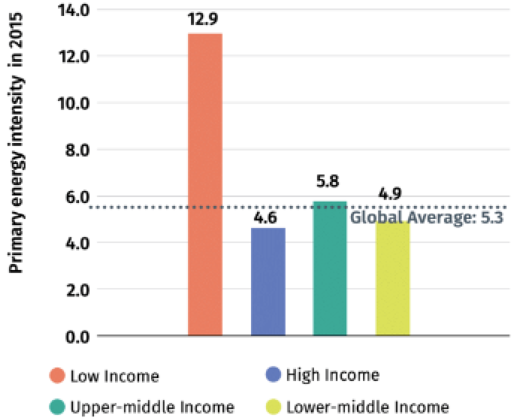
Lecture 8

Why is WTP for Environmental Quality Low in LMICs?

Housekeeping

- First draft due one week from today
- Select your replication paper

Energy efficiency uptake in LMICs



Source: Energy Sector Management Assistance Program (ESMAP), International Energy Agency

Market Failures in Development Economics

- Market failures can shape observed $MWTP_e$
  - And, therefore, environmental policy
- Main frictions: information, credit, risk, or property right imperfections
  - Frictions warp $MWTP_e$, resulting in lower EQ
- **Revealed preference** $MWTP_e$ assumes agent knows payoffs
  - Misinformation common in developing countries
  - Due to literacy, education, information access, state capacity, etc.

Credit Market Failures

- Stem from difficulty writing/enforcing contracts in developing countries
- Costs of monitoring borrowers + enforcing repayment leads to high interest rates and credit rationing (Conning and Udry, 2007)
- Agents cannot pay upfront for clean technology that has future payoffs
  - Forego future improvements in EQ, income, and health
- **Determinants of liquidity therefore confound measured** $MWTP_e$

Missing Risk Markets

- Lower $MWTP_e$ if payoffs are uncertain and insurance unavailable

- Worse EQ can increase var(Y)

- Missing risk markets $\uparrow$ exposure to risk and $\downarrow$ measured $MWTP_e$
  - Liquidity: prioritize income for emergencies, instead of clean water
  - Discounting: undervalue investment in EQ because uncertain about whether will be able to enjoy benefits (discount future more heavily)

Evidence on the effect of market failures on MWTP

- What is the ideal experiment?
- How do you distinguish between measured and actual $MWTP_e$?
- Would random variation help?

" there is hardly a more important topic for future study than developing revealed preference measures of $MWTP_e$ that capture the aesthetic, health, and/or income gains from environmental quality"

- Envirodevonomics (Greenstone and Jack, 2013)

Berkouwer and Dean (2022): Frictions in WTP for Clean Air

- **Research Question:** What are the barriers to adopting clean cookstoves?
- **Setting:** Nairobi, Kenya
  - Test whether credit constraints and inattention to cost-savings lead to underadoption
- **Data:** 1000 households
  - Measure WTP with BDM mechanism
- **Research Design:** RCT with 1000 households to quantify WTP drivers
  - Three-by-three experimental design
  - Cross-randomize two credit and two attention treatments
- **Results:** 1) Stove generates $237 in charcoal savings, 2) yet only $12 WTP, 3) credit constraints are the main friction preventing takeup

Key Idea

WTP for enviromental quality $\rightarrow$ WTP for improved stove

Experimental Setting

Traditional Stove
\$2-\$5

Jikokoa Stove
\$40

- Identical inputs: same charcoal
- Identical usage: almost no learning or behavior change
- Improved insulation materials
  - Better charcoal-to-temperature conversion ratio
  - Ex-ante engineering estimates: 40% reduction in charcoal usage
  - Also generates health and time benefits

Model of Adoption

- Consider agent evaluating an energy efficient technology (costs P_E)
- Adopt iff sum of savings S_t exceed costs today:

$$\underbrace{u(c_0) - u(c_0 - P_E)}_{\text{cost of adoption today}} < \underbrace{\sum_{t=1}^{T} \delta^t [u(c_t + S_t) - u(c_t)]}_{\text{future benefits}}$$

- Agent can take loan L and pay back in payments r_t:

$$\underbrace{u(c_0) - u(c_0 - P_E + L)}_{\text{cost of adoption today}} < \underbrace{\sum_{t=1}^{T} \delta^t [u(c_t + S_t - r_t) - u(c_t)]}_{\text{future benefits}}$$

- WTP P^* is when agent is indifferent

$$u(c_0) - u(c_0 - P^* + L) = \sum_{t=1}^{T} \delta^t [u(c_t + S_t - r_t) - u(c_t)]$$

Model of Adoption

Market Failure Tests

- Agent may be **inattentive** to energy savings by $\theta_s \in [0, 1]$
  - concentration bias: less attentive to small payments r_t
  - Time inconsistency: inattentive to future loan payments $\theta_c \in [0, 1]$

- Agent may be **credit constrained** $L \leq \bar{C}$

Empirical Tests

Main outcome variable: WTP P^*

$$u(c_0) - u(c_0 - P^* + L) = \sum_{t=1}^{T} \delta^t \left[u(c_t + \theta_s S_t - \theta_c r_t) - u(c_t) \right] \quad \text{s.t.} \quad L \leq \overline{C}$$

1. Randomize attention to energy savings θ_s $\qquad \frac{\partial P^*}{\partial \theta_s} > 0$
2. Randomize access to credit $\overline{C}$ $\qquad \frac{\partial P^*}{\partial \overline{C}} > 0$
   - Randomize into N payments of size r_t $\qquad \frac{\partial^2 P^*}{\partial \overline{C} \partial r_t} < 0$
   - Randomize attention to costs θ_c $\qquad \frac{\partial^2 P^*}{\partial \overline{C} \partial \theta_c} < 0$
   - Measure time-inconsistency (TI) $\qquad \frac{\partial^2 P^*}{\partial \overline{C} \partial TI} > 0$

Research Design: Cross-Randomize Credit and Attention

- Each cell contains number of respondents

		Credit Control	Credit Treatment	
			Weekly Deadlines	Monthly Deadlines
Attention Control		96	98	98
Attention Treatment	Energy Savings	96	97	96
	Energy Savings – Costs	145	146	146

Credit: Control and Treatment Groups

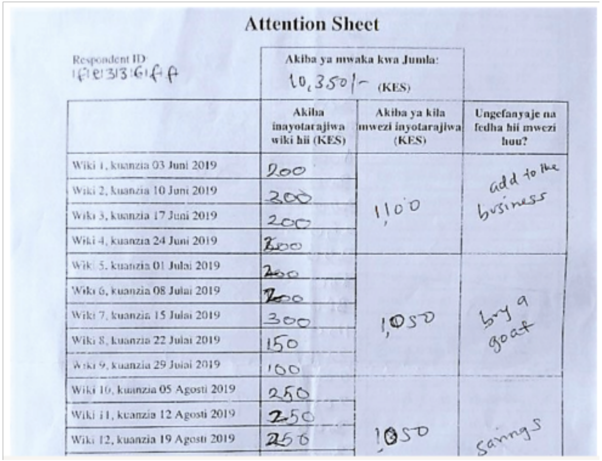
- **Control:** pay (subsidized) price today, receive stove today
- **Treatment:** receive stove today, pay w/n 3 months
  1. Pay by 12 weekly deadlines
  2. Pay by 3 monthly deadlines
- SMS reminders if miss deadlines
- Interest rate of 1.16% per month, 14.8% per year

Attention: Control and Treatment

- **Control:** Informed that stove reduces charcoal use by 50%
  - Informed of $ equivalent of savings
- **Treatment 1:** Attention to energy savings
  - Respondent writes how much they think they'll save
  - Writes down how they will use the savings
- **Treatment 2:** Attention to energy savings minus costs

Attention to Savings

-



Attention Sheet

Respondent ID: [illegible]

Akiba ya mwaka kwa Jumla: 10,350/- (KES)

	Akiba inayotarajiwa wiki hii (KES)	Akiba ya kila mwezi inayotarajiwa (KES)	Ungefanyaje na fedha hii mwezi huu?
Wiki 1, kuanzia 03 Juni 2019	200	1,100	add to the business
Wiki 2, kuanzia 10 Juni 2019	300		
Wiki 3, kuanzia 17 Juni 2019	200		
Wiki 4, kuanzia 24 Juni 2019	200		
Wiki 5, kuanzia 01 Julai 2019	200	1,050	buy a goat
Wiki 6, kuanzia 08 Julai 2019	200		
Wiki 7, kuanzia 15 Julai 2019	300		
Wiki 8, kuanzia 22 Julai 2019	150		
Wiki 9, kuanzia 29 Julai 2019	100		
Wiki 10, kuanzia 05 Agosti 2019	250	1050	savings
Wiki 11, kuanzia 12 Agosti 2019	250		
Wiki 12, kuanzia 19 Agosti 2019	250		

Attention to Savings minus Costs

If the price of the cookstove is USD 38 would you want to buy it?

You would need to pay USD 3 per week for the next 12 weeks.

JUNE
Week 1: You would pay USD 1 (USD 2 – USD 3)
Week 2: You would save USD 0 (USD 3 – USD 3)
Week 3: You would pay USD 0.50 (USD 2.50 – USD 3)
Week 4: You would save USD 1 (USD 4 – USD 3)

JULY
Week 5: You would pay USD 1 (USD 2 – USD 3)
Week 6: You would pay USD 1 (USD 2 – USD 3)
Week 7: You would save USD 1 (USD 4 – USD 3)
Week 8: You would save USD 2 (USD 5 – USD 3)
Week 9: You would save USD 1 (USD 4 – USD 3)

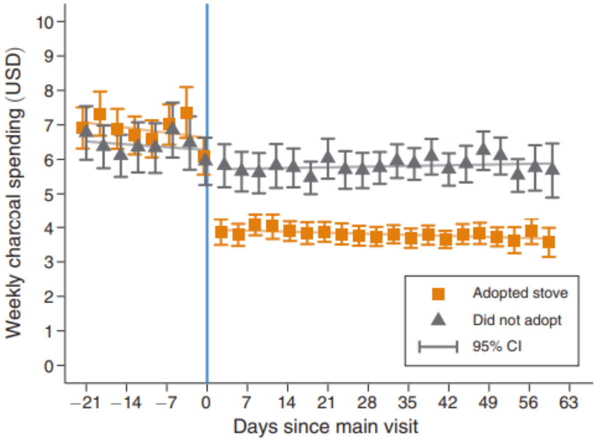
AUGUST
Week 10: You would pay 0.50 (USD 2.50 – USD 3)

Elicit WTP in Each Group

- **Becker-DeGroot-Marschak (BDM) Mechanism**
  - Field worker puts random price $P_i \in (0.01 - 29.99)$ in envelope
  - Elicit max WTP_i from respondent using binary search
  - Open envelope
  - WTP is binding: pay P_i iff $P_i \leq WTP_i$
- Benefits
  - Generates **incentive-compatible** behavior! Why?
  - Adoption is random, conditional on WTP

BDM mechanism elecits WTP AND generates random stove adoption

Stove reduces charcoal spending by $2.28 per week!

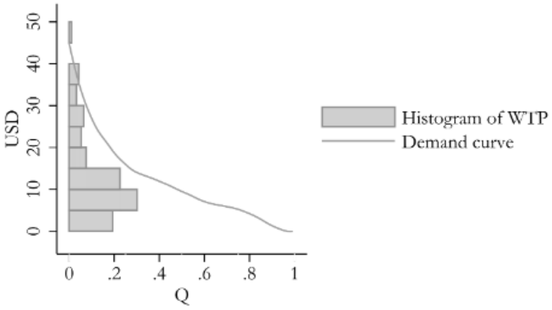


- Large effects: $120 savings per year
- Given $40 cost of stove, this is **300% rate of return!**

Yet, demand is low

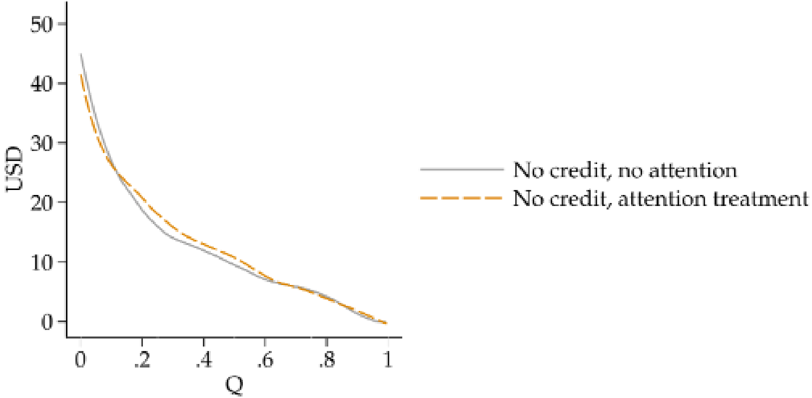
WTP for pure control group (no attention, no credit):

$$Q(P) = Pr(P \leq WTP_i)$$



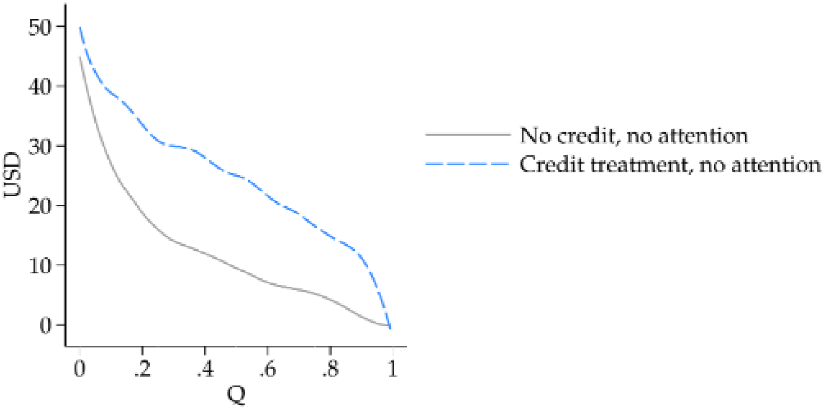
- Control group WTP: Average \$12, median \$10

No evidence of inattention to energy savings!



- Information frictions may not be attenuating WTP

Access to credit doubles WTP!



- credit increases WTP by $13 (104% relative to control)

Other Reasons why WTP is low

- Information access: Baylis et al. (2024), Jalan and Somanathan (2008), Bennear et al. (2013)
- Credit: Ben-Yishay et al. (2017)
- Property rights: Ali et al. (2014), Abman and Carney (2020), Bellemare et al. (2018), Noack and Costello (2024)

Discussion

- Market frictions affects many things $\rightarrow$ endogeneity
- Partial vs. general equilibrium
- Cannot separate measurement from actual distortions
  - Compare across methods more/less affected by frictions?