Willingness-to-pay for long-lasting insecticide treated bed nets: a discrete choice experiment with real payment in Ghana

Y. Natalia Alfonso (corresponding author)ᵃ, Matthew Lynchᵇ, Elorm Mensahᶜ, Danielle Piccininiᵇ and David Bishaiᵃ

ᵃ Johns Hopkins Bloomberg School of Public Health
615 N. Wolfe Street
Baltimore, MD 21205
ynalfonso@jhu.edu
dbishai1@jhu.edu

ᵇ Johns Hopkins Center for Communication Programs
111 Market Place, Suite 310
Baltimore, MD 21202
mlynch@jhu.edu
danielle.piccinini@jhu.edu

ᶜ URIKA Research
Konadu Office Plaza, 1st Floor, Suite 2
Community 4, Tema, Ghana
elormmensah@urikaresearch.com

This research was supported by the Government of the United Kingdom of Great Britain and Northern Ireland, acting through the Department for International Development (DFID) (grant 300191, Components 101,102 and 103). The content is solely the responsibility of the authors and does not necessarily represent the official views of DFID or its member countries.

Declarations of interest: none

Highlights:
• Given a backdrop of fully subsidized undifferentiated long-lasting insecticide nets (LLINs) available for free throughout Ghana, firms would need to gain confidence that they could derive revenue through commercial sale of differentiated LLINs. This study showed that many middle class Ghanaians have significant willingness-to-pay for LLINs with various specialty features.
• Manufacturers interested in making differentiated bed nets can now develop LLIN designs to offer features that are most highly valued among middle-income populations living in the Ashanti, Greater Accra, and Western regions in Ghana.

Keywords:
Malaria; bed nets; long-lasting insecticide nets; insecticide-treaded nets; willingness-to-pay; discrete choice experiment; retails; commercial market; Ghana

Abbreviations:
DCE: Discrete Choice Experiment
LLIN: Long-lasting Insecticidal Net
ITN: Insecticide Treated Net
WTP: Willingness-to-pay
Authors' contributions
All authors conceived of the experiment. YNA conducted the DCE questionnaire design, oversaw data collection, performed the DCE data analysis, and wrote the draft manuscript. DB and ML helped conceptualize the project idea, with experiment development and editing. DB helped oversee the DCE design, data analysis, and contributed to drafting the manuscript. EM managed data collection, assisted with questionnaire development, performed household survey data analysis, and editing. DP assisted with questionnaire development, and oversaw data collection and editing. All authors read and approved the final manuscript.

Acknowledgements
The authors thank URIKA research, a Ghana-based market research firm, for their work administrating the DCE and household surveys. All content remains the authors’ responsibility, however. Thanks also to the participants and numerous school administrators who promoted the experiment and provided space on the school grounds.

Abstract
Introduction: Expanding access to long-lasting insecticidal nets (LLINs) is difficult if one is limited to government and donor financial resources. Commercial private markets could play a larger role in the continuous distribution of LLINs by offering differentiated bed nets to a middle-class Ghanaians, a population segment who has disposable income and is willing to pay for LLINs that meet preferences. Measuring the willingness-to-pay for LLINs with specialty features could help planners estimate the potential for private markets to work alongside fully subsidized LLIN distribution channels to assist in spreading this commodity. Methods: This study conducted a discrete choice experiment (DCE) including a real payment choice among a representative sample of 628 middle-income households living in Ashanti, Greater Accra, and Western regions in Ghana. The DCE presented 18 paired combinations of LLIN features and a variety of prices. Respondents indicated which member of each pair they preferred and whether they would purchase it. To validate stated willingness-to-pay, each participant was given a cash payment of ($14.30 or GHS 65) that they could either keep or immediately spend on one of the LLIN products that they stated they would be willing to purchase. We use the results to compute the public costs and coverage outcomes under scenarios with and without the private LLIN market. Results: DCE results showed that households’ average probability of purchasing a LLIN with specialty features was 43.8% (S.D. 0.07) and the average purchaser’s WTP was $7.48 (GHS34.0). The preferred LLIN features were conical or rectangular one-point-hang shape, queen size, and zipper entry, and the least preferred LLIN features were rectangular four-point-hang shape, double size, and lift-over-head or overlapping-flap entry. The average WTP for a LLIN with all the preferred features was $18.48 (GHS 84). Simulation results show that among the 2.6 million middle-income households living in malaria endemic areas in Ghana, the public sector outlay could be reduced by 42% from $5.5 million to $3.2 million and private LLIN sales would generate $5.4 million in revenue (or $316 per every 100 households in the study area) that would support jobs for Ghanaian retailers, distributors, and importers of LLINs. Conclusion: Our results support a scenario in which commercial markets for LLINs could play a
significant role in improving access to LLINs for middle-income Ghanaians residing in malaria-endemic areas. Manufacturers interested in making differentiated bed nets should focus their LLIN designs to maintain a retail price that could yield sufficient economic return and offer features that are most highly valued among middle-income households residing in malaria-endemic areas in Ghana.

INTRODUCTION
Core malaria control measures have reduced malaria incidence in transmission-intense countries\(^1\).\(^2\). One of the most cost-effective strategies and core prevention tools for reducing the global malaria burden is prevention through use of LLINs. It is estimated that LLINs offer a cost of $27 per disability-adjusted-life-year (DALY) averted from a provider perspective in 2009 dollars\(^3\).\(^4\). They are effective even in areas with mosquito resistance to insecticides.\(^5\) The 2016-2030 Malaria Global Technical Strategy (GTS)’s and World Health Organization (WHO)’s goal is achieving and maintaining universal coverage with LLINs, specifically one net for every two persons at risk of malaria.

Between 2010 to 2016, the proportion of people at risk of malaria in Africa sleeping under an insecticide-treated net (ITN), including LLINs, increased from 30% to 54%\(^6\). Further coverage improvement is needed. Multiple strategies will be required to grow more coverage including mass free net distribution campaigns, continuous distribution channels and the growth of new and currently under-utilized\(^7\) channels, such as commercial sector channels.

However, expanding access to malaria control measures is difficult given the many demands on limited government health budgets\(^8\). One strategy that has gained traction but needs further research is encouraging commercial private markets to play a larger role in the distribution channels for long-lasting insecticidal nets (LLIN). The essential principle is to focus scarce government resources on offering protection to those who cannot afford commercially sold products, but to allow the emergence of an upscale market to take some of the financial pressure off of the government. This pressure relief system cannot take root unless commercial firms choose to enter markets where they are competing against a flood of free products. Commercial private sector sales can be an important source for supplying LLINs to non-poor households willing-to-pay for a LLIN. Commercial sector can also serve as a backstop for poor households in the event that public sector funding and channels cannot supply enough nets to increase coverage or replace worn-out nets\(^4\).

Prior to the era of publicly-funded mass distribution campaigns for LLINs, a commercial market for LLINs existed in several African countries. While mass campaigns rapidly increased ownership of LLINs bringing major benefits to millions of families, it came at a cost to the commercial market, which has diminished due to a lack of incentives for the private sector given users’ dependency on donor-provided free nets. The absence of a commercial market puts the entire financial burden of LLINs on the public sector and that burden can be overwhelming.

In 2016, governments and international partners spent US$ 2.7 billion on global malaria control and elimination (e.g. below $2 per person at risk of malaria)\(^6\). Out of the total, 74% was spent in Africa and those governments’ contribution was 31%. This expenditure will need to triple by 2030 in order to meet global malaria reduction targets\(^1\).\(^6\).\(^9\). Additionally, 2014 data from Ghana show that households also bear a significant cost paying an average of $2.10 and $11.8 out-of-pocket (OOP) in direct and indirect costs, respectively, per malaria treatment at formal health facilities. Local businesses\(^10\) in high-burden countries are also affected through increased staff absenteeism and private healthcare costs. While the World Health Organization (WHO) predicted that 21 countries could eliminate malaria by 2020, 11 of these have shown marginal but consistent increases in malaria cases and another 25 countries, mostly in
Africa, show case increases of 20% \(^6,8\). One contributory cause for stalled progress is a lack of sustainable and predictable funding \(^8\). As the stakes for controlling malaria increase, strengthening and identifying efficient strategies to widen funding sources for LLINs is crucial.

Little is known about the potential demand for high quality LLINs that could be sold in commercial markets, particularly among households who are not in poverty. Three studies in Tanzania, Madagascar and India, that used rigorous consumer preference measures, found low demand for LLINs among mostly poor-income households, however responses indicated the potential to make demand strong through micro-consumer loans and voucher subsidies\(^{11-13}\). The study in Tanzania found strong demand (44\%) for LLINs among the least-poor households and higher willingness-to-pay for LLINs that matched consumer preferences for nets’ shape and size. However, the focus of the Tanzania study was not on non-poor households. (The share of the non-poor population needing LLINs in high malaria risk countries in Africa is 52\%)\(^{14}\). It would be important to understand the potential size of the commercial market to inform decision-making on how this distribution channel can be strengthened to help alleviate the access and funding gaps in malaria prevention.

This study seeks to evaluate the demand and willingness-to-pay (WTP) for LLINs with characteristics that match consumer preferences among the non-poor middle-income households in a high malaria risk country such as Ghana. The study assesses whether there is a statistically significant demand for buying LLINs among non-poor and middle-income Ghanaians and determines what LLIN features or “attributes” consumers find most attractive. Finally, the study estimates how many LLINs are likely to sell and the net incidence of costs and savings on the government in a scenario where all LLINs are distributed free versus a scenario in which only the poor get subsided LLINs.

**METHODS**

**Data**

We evaluated the demand and WTP for LLINs among a representative sample of middle-income households from three regions in Ghana, Ashanti, Greater Accra, and Western, using a discrete choice experiment (DCE) with a real payment choice. A DCE is a quantitative technique based on conjoint-analysis theory that elicits consumer stated preferences from a target population. The DCE technique was selected over other stated preference techniques, such as contingent valuation, because it allows for the valuation of trade-offs between multiple net characteristics or “attributes” (i.e. size, shape, etc.) and characteristic types or “attribute levels” (i.e. color types: white, blue, green, etc.)\(^{15}\). DCEs are a widely applied approach in research associated with health commodities\(^{16}\).

**Study Population**

The study targeted the regions in Ghana where people are at risk of contracting malaria, have the lowest saturation of household LLIN ownership and have purchasing power to buy their own LLINs. This last criterion ensured that the evaluation focused on the areas with the potential to capture a market share for a sustainable commercial market of LLINs. Out of the ten regions in Ghana, Ashanti, Greater Accra, and Western had the lowest poverty incidence (15\%, 5.6\%, and 21\% respectively), were the most urbanized (64\%, 92\% and 45\% respectively) and had low LLIN ownership (70\%, 61\% and 67\%, respectively owning at least one LLIN)\(^{17,18}\). Within these three regions, the study focused on the 28 non-poor districts, according to the 2015 Ghana Poverty Map (i.e. districts with poverty rates lower than 9.6\%)\(^{19}\). Individuals eligible to participate in the household survey and DCE were adults (18+ year olds) household members that had knowledge about the household use of bed nets and finances.

**Sampling**
A cross-sectional study design was used. Out of 1075 households recruited for a broader LLIN household survey, evaluating malaria ideation and LLIN usage among the same study population, a random sub-sample of 628 households was selected to take part in the DCE. The sampling frame used a stratified two-stage cluster sampling method, see Appendix A for sampling details.

Given the number of attributes levels (13) and choice set alternatives (3) included in the DCE (see DCE sections below for details), we estimated that a minimum sample size of 600 respondents would provide sufficient statistical power for the DCE based on having a minimum of 50 respondents per alternative plus an additional 50 (3 alternatives x 50 = 200)²¹,²² and 200 participants per sub-group analysis (200 x 3 regions = 600)²³. This sample size was similar to prior literature²⁴ and also met other literature’s minimum criterion of 30 respondents for every level tested²⁵ (13 levels x 30 = 390) in order to statistically significantly differentiate the effect of price between different attribute levels. An oversample of 28 participants yield to a total of 628 DCE participants recruited.

**Identifying the DCE attributes and assigning attribute levels**

The selection of LLIN attributes and attribute levels included in the questionnaire was supported by data from a pilot DCE with 50 respondents and qualitative techniques collected from the same study population²⁶. These mixed research methods were designed to inform the DCE about which LLIN attribute improvements were most desired, affordable and feasible for manufacturing. Qualitative techniques included focus groups (with 60 adults and 30 teenagers) employing both semi-structured opened-ended questions²⁶ and human-centered design (HCD) study to understand people’s facilitators and inhibitors to LLIN use as well as their LLIN product preferences, retail audit reviews, key informant interviews with LLIN supply chain importers and wholesalers and recommendations from malaria program experts.²⁷²⁷ See Table 1 for the final list of four attributes (i.e. shape, size, entry-design and price) and each of their levels (for a total of 13 levels). The attributes of shape and entry-design each included 3 levels. The attribute of size included two levels, and price included 5 levels. The minimum and maximum price values tested were $1.10 (5 GHS) and $14.30 (65 GHS). The maximum price was equivalent to a 25% margin above the cost for manufacturing and distributing the LLIN with the combination of all the most expensive attribute levels in a LLIN (i.e. size queen, zipper entry, rectangular 4-point-hang). The maximum LLIN price estimate was $11.44 (GHS 52) and this value was derived from the key informant interviews data obtained from LLIN supply chain importers and wholesalers.

<table>
<thead>
<tr>
<th>LLIN Attributes</th>
<th>Attribute Levels</th>
<th>No. of Levels (13)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shape</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conical</td>
<td>Rectangular four-point hang (R4p)</td>
<td>3</td>
</tr>
<tr>
<td>Rectangular single-point hang (R1p)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Double</td>
<td>Queen</td>
<td></td>
</tr>
<tr>
<td><strong>Entry design</strong></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Lift over head</td>
<td>Flap overlapping</td>
<td></td>
</tr>
<tr>
<td>Zipper</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Price (GHS)</strong></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>50</td>
<td>65</td>
<td></td>
</tr>
</tbody>
</table>

Note: The 13 attribute levels were the final list out of 17 levels considered for the model. See the appendix for details on the inclusion criteria for attribute levels.

**Designing the DCE choice sets**

The DCE survey instrument was composed of 18 choice questions. Each choice question provided participants three alternatives, whether to buy “LLIN A”, to buy “LLIN B”, or to buy neither “to opt out”. LLIN alternatives A and B each specified an attribute level for each attribute tested in the model.
The different types of LLINs that could be created combining 13 attribute levels from four attributes is 90 (=3 x 2 x 3 x 5). These 90 LLINs could be combined into (90 x (90-1)) = 8,010 choice pairs (i.e. LLIN choice A or B), known as the “Full Factorial Design”. This large array of choice questions was reduced to a manageable number using orthogonal fractional factorial design (FFD)\textsuperscript{15,28,29}, a statistical technique commonly used for DCE designs that draws a small sample of choice-pair-questions such that each attribute level appears enough times in the survey for the analysis to capture the effect of changes to each level on the probability of purchase ("LLIN demand"). The maximum and minimum number of survey questions recommended for a DCE, while ensuring collection of enough data for drawing statistical inferences but reducing participant exhaustion, is between $K / (J-1)$ and 18, where $K$ is the number of attributes (4) and $J$ is the number of choice “alternatives” (A, B, Neither = 3), thus between 2-18 questions. As such, we designed a survey with the maximum of 18 choice questions to maximize statistical power (15 choice question designed using the FFD and 3 choice questions designed to test for participants’ response rationality and consistency), see Appendix B for details and the questionnaire design. The FFD was calculated using the statistical software R version 3.4.3.

**Binding intention to buy the product**

The DCE survey questions asked participants: “Which LLIN are you most likely to purchase: Bed Net A, Bed Net B, or Neither A nor B is preferred?” To mimic as close as possible an everyday purchasing situation, each participant was given money to elicit a validated “bidding” purchase choice (i.e. a true stated preference) instead of a hypothetical choice\textsuperscript{27}. Each respondent received a cash payment of $14.30 (65GHS) in local currency, an amount that was sufficient to pay for the most expensive LLIN price level that could come up in any of the survey choice questions. Thus, for each of the 18 choice questions, respondents knew they would be immediately able to buy any LLIN option if they wanted to buy it. They would retain the remaining change (difference between $14.30 and the LLIN price value specified in the alternative). They were explicitly told they could opt out and keep all of the cash—just like in a real shopping situation.

It was not logistically possible for survey administrators to carry 18 types of nets with them in the field so only four real nets were stocked. At the end of the survey an electronically generated number randomized one out of the four survey questions for which sample nets were available. Survey administrators where blind to the randomly generated number. The respondent’s actual stated preference corresponding to the randomly chosen final question was reviewed with them and based off their response the participant received either Net A and the balance of remaining change, Net B and the balance of remaining change, or all of the cash payment and no net. Participants were alerted from the outset about the way in which their stated preferences would be made binding and have real consequences.

Prior to reading the questions, contextual information about the study was provided, each attribute and level was defined using both standardized text and 11x11 inch laminated cards with pictures, each of the 18 choice sets was also illustrated on three-choice card-sets with attribute pictures, and the experiment was preceded by a practice mini DCE about candies to help participants understand the exercise, see Appendix B for details. DCE survey facilitators were trained in administrating the survey and answering participant questions. Participants signed consent forms and interviewers administered the DCE survey using electronic tablets. DCE survey questions appeared in random order and the order in which each question was answered for each participant was recorded and used in the analysis as a control for participant survey exhaustion for the later questions. See the Appendix B for DCE design and procedure details. All research activities with human subjects were reviewed and approved by the internal research review boards (IRB) from both the Johns Hopkins University and Ghana Health Service.
**Statistical Strategy**

Assessment of LLIN demand was done using multivariate logistic regression with random effects, a model of observation errors clustered by person-question-ID to correct for unobserved or random preference variation\(^23\), with controls for attribute levels, competing alternatives, and respondents’ demographic and socio-economic characteristics, using the following equation:

\[
BuysLLIN = \beta_0 + \beta_1 Price + \beta_2 Shape + \beta_3 Size + \beta_4 EntryDesign + \beta_5 OtherALTlevels \\
+ \beta_6 SES + \beta_7 HHmmbrs + \beta_8 Qorder + \beta_9 InterviewID + \beta_{10} Price * Female \\
+ \beta_{11} Price * Rural + \varepsilon
\]

Although a respondent was making only 18 declarations of (A, B, or Neither), we can view the exercise as a set of 36 forced choice binary declarations of “Yes I would buy the option on this card” albeit each of these declarations was made in the context of a defined competing alternative. BuysLLIN is a binary response variable equal to one if the respondent chose to declare an intention to buy one net out of a pair and zero otherwise. Price is the LLIN price coded as a continuous variable. As shown in Table 1 above, shape is a vector of three shape levels, including rectangular 4-point hang (R4p), rectangular 1-point hang (R1p) and conical (which is the base-level omitted in the analysis), coded as a set of dummy variables; size is a dummy equal to one for queen and zero for double; and entry design is a vector of three entry design levels, including lift-over-head, zipper, and the base-level flap-overlapping. Coefficients can be interpreted as the change in the probability of buying a LLIN with that attribute level compared to the base-level, holding other variables at their means.

OtherALTlevels is a set of vectors of the Price, Shape, Size, and EntryDesign of the alternative card that was the context for the one that was under consideration. The model included various socio-demographic variables (SES) about the respondent, including: a sex dummy equal to one for females and zero otherwise, a secondary education dummy, a married dummy, a vector of three region variables, including Ashanti, Western and the base-level Greater Accra, a SES vector of five wealth dummies (all pertaining to “non-poor” Ghanaians) where the base-level is the lowest wealth, a dummy for residency type equal to one if rural.

HHmmbrs is a continuous variable on the number of household members. Qorder is a continuous variable on the order in which that survey question appear during the survey administration, InterviewerID is a vector of all 12 survey interviewer ID dummies added to control for the influence of individual interviewers on the choice to buy, and lastly, Female*Price and Rural*Price are interaction terms on the difference between the price females and males pay, and between the price individuals in rural and urban areas pay, respectively.

The error term, \(\varepsilon\), was modeled as a random intercept that could be decomposed into components from within individual and within a particular card set to account for the non-independence of observations that were clustered.

Three of the 18 questions had been planted only to test for invalid responses (e.g. they contained “no brainer” options where one alternative was superior across all domains). The analysis was run on the subset of 15 questions that were from the FFD. The logistic regression coefficient values were converted to marginal effects to ease their interpretation as elasticities of the probability of purchase. Demand curves plotted the predicted probability of purchase from the model vs. price. Estimates of average total revenue (ATR) at any given price was calculated as the product of price times probability of
purchase for every 100 individuals encountering an opportunity to purchase. Over 50 regression specifications were tested adding one SES, or other respondent background variable a time and testing robustness (i.e. consistency) of results. We also explored robustness of results to the removal of irrational, inconsistent or always-buyers (“disengaged”) responses. Probability of purchase and WTP estimates were stratified by key LLIN attributes and individual characteristics. We also measured the probability of purchase for the least and most attractive LLINs at the average WTP price as well as at the low and high price points of $4.40 and $13.20 (GHS 20 and 60). The analysis was computed using STATA software version 14.

Lastly, we estimated the total public cost for two scenarios. In scenario one the public sector buys at least one LLIN for households in a defined population. In scenario two there is a commercial market that conforms to the WTP estimated by the model. Our policy analysis computes the public costs and coverage outcomes under these two scenarios. A Monte Carlo simulation with 1,000,000 iterations of the model was ran to produce confidence intervals around cost and savings estimates.

RESULTS

Descriptive statistics
Among the 628 DCE participants, a majority were females (61.3%), had secondary education (70.0%), were heads of the household (75.2%), about half were over age 35 and married (52.2%), most lived in urban areas (89.2%) and were employed, see Table 2. The majority of households (69.3%) did not have a bed net and had an average of 3.1 members per household. Among the minority (30.7%) with a bed net, net ownership was an average of 1.7 nets per household, but only 0.9 reported using it. Furthermore, the majority believed that malaria is not easy to treat, that insecticide-treated nets are effective and it is easier to get a good night sleep when sleeping under a bed net but also that it’s difficult to sleep well under it when the weather is warm. See the Appendix C for more on net ownership and malaria ideation.

Table 2. Study Population Descriptive Statistics, Total n=628
Internal Validity

Internal validity tests revealed that 9.24% (58), 5.41% (34) and 48.25% (303) of participants made choices that were irrational, inconsistent or anchored to buying every choice ("always-buyers"), respectively. See Appendix C Tables 2 and 3 for details. Knowing that some DCE respondents violated assumptions about rationality and consistency led us to restricted results the sub-sample of 541 respondents who were neither irrational nor inconsistent.

The LLIN Demand Curve

The sample had an overall probability of purchasing a LLIN of 43.8%. On average, purchasers were willing to pay $7.48 (GHS 34.0) for a LLIN across all presented attributes. For every 100 middle income Ghanaian households in the study areas, the average total revenue (ATR = price x quantity) would be $327.49 (or GHS 1,488.61). The difference in the mean probability of purchase between those who already owned and those who did not own at least one net was a 1.5% percentage point difference (p-value<0.00). As expected, price negatively affected the probability of LLIN purchase. For every price increase of $0.22 (or GHS 1), the probability of purchase decreased by an average of 0.13% (p<0.00), holding all other net attribute levels and respondent characteristics at their means, see Table 3.
## Table 3. Estimate of the DCE demand model

<table>
<thead>
<tr>
<th>Demand change in the demand for LLINs when:</th>
<th>Demand Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price increases by USD 0.22 (or GHS 1)</td>
<td>-0.13% ***</td>
</tr>
<tr>
<td>The shape attribute level changes from:</td>
<td></td>
</tr>
<tr>
<td>Rectangular R4p to R1p</td>
<td>2.22% **</td>
</tr>
<tr>
<td>Rectangular R4p to Conical</td>
<td>3.56% ***</td>
</tr>
<tr>
<td>Rectangular R1p to Conical</td>
<td>1.33%</td>
</tr>
<tr>
<td>The size attribute level changes from:</td>
<td></td>
</tr>
<tr>
<td>Double to Queen</td>
<td>3.31% ***</td>
</tr>
<tr>
<td>The entry design attribute level changes from:</td>
<td></td>
</tr>
<tr>
<td>Lift over head to Flap overlapping</td>
<td>-0.39%</td>
</tr>
<tr>
<td>Lift over head to Zipper</td>
<td>3.83% ***</td>
</tr>
<tr>
<td>Flap overlapping to Zipper</td>
<td>4.22% ***</td>
</tr>
<tr>
<td>Female instead of male</td>
<td>-0.31% ***</td>
</tr>
<tr>
<td>Age changes from 18-25 to</td>
<td></td>
</tr>
<tr>
<td>Age 26-35</td>
<td>0.17%</td>
</tr>
<tr>
<td>Age 36-45</td>
<td>-0.63%</td>
</tr>
<tr>
<td>Age 46-55</td>
<td>-2.08% ***</td>
</tr>
<tr>
<td>Age 56-65</td>
<td>-1.53% *</td>
</tr>
<tr>
<td>Age +65</td>
<td>-2.09% *</td>
</tr>
<tr>
<td>Education attainment is secondary school</td>
<td>-1.03% ***</td>
</tr>
<tr>
<td>Married</td>
<td>-0.11%</td>
</tr>
<tr>
<td>SES status changes from lowest to:</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>0.87%</td>
</tr>
<tr>
<td>Middle</td>
<td>0.22%</td>
</tr>
<tr>
<td>High</td>
<td>1.00% *</td>
</tr>
<tr>
<td>Highest</td>
<td>-1.52% **</td>
</tr>
<tr>
<td>Rural area</td>
<td>0.99% ***</td>
</tr>
<tr>
<td>Number of household members</td>
<td>0.15%</td>
</tr>
<tr>
<td>Survey exhaustion (question order)</td>
<td>0.06% *</td>
</tr>
<tr>
<td>No. of respondents</td>
<td>541</td>
</tr>
<tr>
<td>No. of observations (questions)</td>
<td>16,230</td>
</tr>
<tr>
<td>No. of clusters (person-question ID. obs.)</td>
<td>8,115</td>
</tr>
</tbody>
</table>

Note: R4p and R1p is rectangular 4-point hang and 1-point hang, respectively. Shape conical was illustrated and described to participants as a 1-point hang. Analysis excludes irrational and inconsistent respondents. The number of asterisks indicate the level of statistical significance where: *** is p-value <0.00, ** is p-value<0.05, * is p-value 0.10, and no asterisk means not statistically significant. The list of interviewer dummies is not shown to reduce the length of the table. The marginal effect for each region and price interactions were not estimable. However, we show results for each region in the table of stratified analysis.

The range of LLIN prices tested in the DCE was $1.10-14.30 (GHS 5.0-65.0). Figure 1 shows that within this price range, the price elasticity of demand was inelastic with an average elasticity of -0.11 (C.I.: -0.087 to -0.13). This means that changes in the price only produce modest changes in the quantity demanded. An elasticity of -0.11 means that a one percent increase in the LLINs’ price would decrease demand by 0.11% (on average, a one percent price hike would equal $0.07 or GHS0.34). Because of the inelasticity,
increasing the price by one percentage point above the average would increase total revenue from $327.49 to $366.85 in a population of 100 middle income households. The proportion of respondents willing to pay the highest price tested in the analysis, $14.30 (GHS 65.0), was only slightly lower than the proportion willing to pay for the average WTP (39.5% vs. 43.8%). Thus, at the highest price tested of $14.30, the average total revenue would be $565.06 (or GHS 2,568.44) per 100 households. See Appendix Tables 4a-4b for tabulations of demand probabilities and price elasticities of demand by WTP.

Figure 1. Long-Lasting Insecticide Treated Bed Nets (LLIN) Demand Curve

Effect of Attribute Changes on Demand
Table 3 also shows the effect of substituting LLIN attribute levels on the probability of purchase. The tradeoff between the LLIN shape from R4p to R1p, or from R4p to conical, increased the average probability of purchase by 2.22% (p<0.05) and 3.56% (p<0.00) percentage points, respectively. The difference in probability of purchase between R1p and conical was not statistically significantly different. Increasing net size from double to queen increased the demand by 3.31% (p<0.00) and changing the net entry design from either lift-over-head or flap-overlapping to a zipper increased the demand by 3.83% (p<0.00) and 4.22% (p<0.00), respectively. The difference in the demand between lift-over-head and flap-overlapping was not statistically significantly different.

Effect of Respondent Characteristics on Demand
Various sociodemographic characteristics also statistically significantly changed demand for LLINs. Males’ had a slight 0.31% percentage point (p<0.00) higher demand than females. Demand was also slightly higher among the 18-25 age group by 2.08% percentage points (p<0.10 and 0.00) compared to the older respondents age 46 or older. Having a secondary education or being from the highest income group (within our middle-income population sample) slightly decreased demand by 1.03% (p<0.00) and 1.52% (p<0.05), respectively. Living in a rural area also increased demand by 0.99% percentage points (p<0.00) compared to urban areas. Lastly, the effect of respondents’ survey exhaustion (0.06%, p<0.1)
and some individual interviewer IDs (list not shown in the table) was also statistically associated with changes in demand.

Sensitivity Analysis of Demand Changes
Some analysts believe that real consumers exhibit features of non-rationality and anchoring in their market behavior. Thus, we examined whether the results would change if models included responses from the full sample including respondents who showed irrational or inconsistent choice behavior. In general, findings were very similar to the main results, see Appendix C Table 5.

Similarly, we examined results excluding the sub-group (n=303) who anchored to always buying one alternative out of each 18 choice-sets. Removal of the always-buyers made the shape R1p not statistically preferable to the R4p (i.e. conical was the overall preferred shape), see Appendix C. But, including the always-buyers made both the R1p and conical shapes preferable to the R4p. As before, there was no statistically significant difference between conical and R1p. This may indicate that the R1p feature was especially appealing to this subset of always-buyers.

Stratification of Analysis by Sub-Populations
Sub-group analysis of individuals with and without LLIN in the household, females vs. males, and urban vs. non-urban were generally the same with demand elasticities ranging between 0.04% to 0.15% (p-values<0.00). See Appendix C Table 6.

LLINs Attribute Level Combinations Most and Least Likely to Increase Demand
Figure 2 shows that changing LLIN attributes from the least attractive levels of every attribute (e.g. R4p, double size, lift or flap entry) to the most attractive (e.g. conical or R1p, queen size, and a zipper entry) shifted the demand curve. Holding the average probability of purchase constant (43.8%), see Figure 2, changing all the LLIN attributes from the least to most attractive increased the average WTP from $3.30 (GHS 15) to above the $14.30 (GHS 65) price tested, predicted at $18.48 (GHS 84), respectively. Re-engineering product attributes from the worst to most attractive LLIN would improve ATR from $144.48 (GHS 656.74) to $809.10 (GHS 3,677.73) in a population of 100.
If we believe our sample is representative of all the 2.6 million households living in the three study areas (e.g. districts with lower than the average poverty rate: 0.7%-9.6%) we can extrapolate from our sample to the study population. We assume that the current coverage levels are met and the cost per LLIN is the manufacturers’ price of $4.38. With these assumptions, the total cost of providing the standard unenhanced LLIN to each current owner (0.87 million HHs) would be $3.7 million in 2017. In an alternative scenario in which the commercial market offers an enhanced LLIN for sale at a price of $7.48 per LLIN, we project private sales of LLINs producing revenue valued at $8.1 million (95% C.I.: 5.9M-10.6M) to 1.08 million non-poor households (or $311 per every 100 households in the study area). Revenue from private sales would support jobs for Ghanaian retailers, distributors, and manufacturers of LLINs. Total LLIN coverage would increase by 85% from new LLIN owners from non-poor households who did not already have an LLIN. Of note, we project that the public sector outlay would be reduced by 39% (95% C.I.: 50.30%-27.89%), from $3.7 million to $2.3 million, from people who are now buying their own LLINs, rather than relying on the ones given through free distribution. See the Appendix Figure 1a and Tables 7a-b for model calculations and parameters. Estimates assume a conservative scenario in which all poor households do not buy LLINs. The Appendix shows additional estimates for scenarios in which LLINs are purchased to close the LLIN coverage gap as opposed to meet current coverage levels.

**DISCUSSION**

Our results support a scenario in which commercial markets for LLINs could play a significant role in improving access to LLINs for non-poor Ghanaians prone to malaria, where significant proportion of the households do not own or use bed nets. Local market research data suggests that lack of ownership and usage among this population may be due to low supply of nets that consumers like. For instance, only...
7% of local markets in the study area sold nets and those most commonly available had the combination of characteristics that were least preferred out of all the attributes tested in the DCE: rectangular 4-point-hang, size double, and lift overhead entry LLINs. Likewise, out of the net owners only about half used the nets and most were obtained free from public distribution campaigns.

Our study showed that with net attributes matching consumers’ preferences there would be a strong demand for LLINs with 44.8% of current net owners and 43.3% of non-net owners asserting and demonstrating a willingness to purchase. The study validated their statements by observing not just their statements in a DCE but their actual purchases with money that they could have kept for any alternative use.

Respondents showed a mean willingness-to-pay of $7.48 that was much higher than the mean price of $4.38 for imported nets currently sold in local markets. The price elasticity for LLINs was inelastic, thus, changes in price around the range we tested will not significantly decrease demand. However, at prices higher than the price tested in this analysis (e.g. $14.30) the price elasticity of demand may be elastic (see limitations below).

Results also revealed that improvements to LLINs by improving various attributes can increase demand for LLINs from 2.22% and up to 8.27% percentage points. Similarly, the average WTP for the most “attractive” LLIN was $18.48 or for the average type of LLIN in Greater Accra was $17.14 greater than in Ashanti, both of which are more than four times the mean prince of the LLINs sold in local markets. The market potential to increase the demand for LLINs is contingent on manufacturers and local retailers being able to supply and market LLINs with the attributes consumers prefer.

Our results indicate individual characteristics, such as living in a rural area, being male, being less wealthy and living in Ashanti were also associated with higher LLIN demand.

Private and public strategies encouraging commercial markets for LLINs will help increase the population’s access to LLINs as long as there remains a public commitment to ensure access to LLINs for those for whom out of pocket payments are a barrier. Building a stronger LLIN commercial market could spare the public sector more than half of the cost of supplying free LLINs to individuals who have the means and willingness to buy LLINs with preferred features. The demand exists to generate substantial revenue for a commercial market that would create new jobs for Ghanaians (i.e. creating economic opportunities for local retailers). The strong demand for LLINs also has the potential to increase LLIN usage because individuals would be getting a product that they like.

Other studies
Six studies in sub-Saharan Africa have looked at the WTP of LLINs, including one from Ghana. All studies find a negative association between price and demand, but some find different levels of demand and WTP. However, studies with different results either suffer from significant bias based on the methods used to estimate WTP or target individuals from poor settings, making results incomparable. For example, Gingrich et al (2017) also using a DCE in Tanzania (testing preferences for insecticide-treatment, shape, and size) found similar results. They found significant demand for LLINs, inelastic price elasticity (among both poor and least poor populations), increased demand for add-on features (e.g. rectangular, larger size, and insecticide-treatment), and higher demand in rural areas. However, their study found a much lower WTP (between $0.5 to $1.4). The difference between their results and ours may be explained by their study’s design for which the price cap tested was significantly lower than that for this study (8000TSH or about $3.5 compared to our upper value of $14.30) and because they also
targeted poor-income groups which would have lowered the mean WTP due to lower purchasing power. Another study in Ghana using an auction found a significant WTP for a solar-panel net-fan (about $13), suggesting that their fan product could be a bed net complementary good, thus potentially also increasing the demand for bed nets\textsuperscript{30}. However, they did not measure WTP for bed nets.

Two other studies, in Ethiopia\textsuperscript{31} and Nigeria\textsuperscript{32}, found a very large probability of LLIN purchase with low WTP and an elastic WTP. However, both studies employed direct consumer survey stated preference techniques which are less robust than conjoint analysis \textsuperscript{33}. Another study in Madagascar by Comfort and Krezanoski (2017), using revealed preference data from a RCT field experiment and subsidizing LLINs at 0%, 25%, 50%, 75% and 100% for a maximum cost of $2.20 among low-income groups, found a very elastic price of demand for the higher prices, where for each $0.55 increment, demand decreased by 23.1\% points\textsuperscript{11}. Similarly, Tarozzi et al (2014) using a field experiment in India found very elastic prices of demand for LLINs among poor individuals, where demand decreased 50\% when the price increased by 20\%\textsuperscript{12}. Likewise, Dupas (2014) using subsidies in a field experiment in Kenya found elastic LLIN prices\textsuperscript{34}. These three field experiments are consistent with prior literature by Cohen and Dupas (2010) indicating high price elasticity of demand for health products among poor households\textsuperscript{35}. We believe that the diminished price sensitivity of our sample is to be expected precisely because we intentionally sampled non-poor households for whom the next best use of funds was much less likely to be an essential need.

Limitations
Our results are unlike prior findings about households including poor communities, for which the price elasticity of demand for LLINs is typically elastic. Our evidence is consistent with higher-income individuals being less responsive to changes in prices than low-income individuals\textsuperscript{36}. However, in our study estimates are restricted by the top LLIN price tested, $14.30. It is possible that higher prices than those we tested would have revealed more sensitivity to the price. Future experiments involving middle-income populations would need to incorporate wider price ranges to determine the price elasticity at higher LLIN prices\textsuperscript{37}.

DCE can be limited when there is poor respondent understanding of attribute levels or cognitive fatigue. However, we mitigated this bias by piloting the DCE so that the study instruments could improve contextual information. The study used pictures illustrating each of the 18 question choices and each attribute level. The DCE module occurred early in the household survey modules to reduce respondent fatigue, and included a simple 2-question DCE for practice before administrating the actual DCE to respondents. Similarly, survey administrators reported in general having no issues with participants’ understanding of the various attribute levels or the exercise. Likewise, to mitigate the influence of priming respondents about the importance of malaria, which could bias results upward, we administered the malaria ideation question after the DCE.

Likewise, prior studies have suggested that providing a cash transfer might bias choice behavior upward toward buying. However, the study design took pains to emphasize that the respondent could absolutely keep the endowment if they did not spend it on the purchase of a net. The presence of the cash transfer in the study was a necessary component for this DCE to validate stated preferences with observed real market behavior\textsuperscript{12,33,38}.

Lastly, a sub-set of our study population behaved irrationally or anchored to buying a net for all 18 survey choice-questions in the experiment. Such behavior could bias choices data if participants are not providing their actual preference between the various net features. Excluding the 303 households anchoring to always buying made the shape rectangular-1-point-hang not statistically preferable.
indicating that this feature is especially appealing to this subset of always-buyers. Other than this difference, sensitivity analysis showed results where robust to the removal of either irrational respondents or always-buyers.

An important strength of our study is that the respondents knew there was money at stake. They knew they would have to back up their statements of willingness to purchase LLINs with actual purchases of the nets they said they would purchase at the prices they agreed to. They knew they could leave the encounter with cash payments if they felt they were better off with having cash instead of immediately using the cash to purchase an LLIN. This design feature improves the internal validity and helps us support claims that stated preferences and willingness to purchase is reflective of actual revealed preferences about how people would spend their own money on. However, there may still be some left over social acceptability bias that may have skewed some respondents to be more willing to spend their new cash on the offer of a LLIN.

**Policy Implications**

Using rigorous techniques from a sample of middle-income households in Ghana, this study shows that there is a strong demand for LLINs in the private market, particularly for LLINs with the characteristics that meet consumers’ preferences. This evidence shows that the private commercial sector could be a viable channel for distributing LLINs. This could help increase LLIN coverage, and help the public sector save money from households buying their own nets. Evidence from this study may help manufacturers and retailers better understand the revenue opportunities linked to supplying key consumer-preferred LLINs. The public and donor sectors should incorporate policies into their national malaria prevention plans supporting commercial markets for consumer-preferred LLINs. However, policies would have to remain in place that assist poor households in acquiring LLINs so that an equitable market could combine both efficiency and fairness.

**BIBLIOGRAPHY**


