Published by Oxford University Press in association with The London School of Hygiene and Tropical Medicine *Health Policy and Planning* 2011;**26**:133–141

doi:10.1093/heapol/czq027

Household demand for insecticide-treated bednets in Tanzania and policy options for increasing uptake

Chris D Gingrich,[1]* Kara G Hanson,[2] Tanya J Marchant,[3] Jo-Ann Mulligan[2] and Hadji Mponda[4]

[1]Department of Business and Economics, Eastern Mennonite University, Harrisonburg, VA, USA, [2]Health Economics and Financing Programme, London School of Hygiene & Tropical Medicine, London, UK, [3]Faculty of Public Health & Policy, London School of Hygiene & Tropical Medicine, London, UK and [4]Ifakara Health Institute, Dar es Salaam, Tanzania

*Corresponding author. Department of Business and Economics, Eastern Mennonite University, 1200 Park Road, Harrisonburg, VA 22802, USA. E-mail: chris.gingrich@emu.edu

Accepted 19 March 2010

There has been considerable controversy about the most appropriate means of delivering insecticide-treated nets (ITNs) to prevent malaria. Household demand for ITNs is a key factor influencing the choice of delivery strategy, but evidence to date about price and income elasticities comes either from studies of hypothetical willingness to pay or small-scale policy experiments. This study estimates the price and income elasticities of demand for ITNs using nationally representative household survey data and actual consumer choices, in the context of a national scheme to provide vouchers for subsidized nets to pregnant women in Tanzania. Under this distribution system, the estimated price elasticity of demand for subsidized ITNs equals −0.12 and the income elasticity estimates range from zero to 0.47, depending on household socio-economic status. The model also shows a substantial decline in short-term ITN purchases for women whose household received a free ITN.

These findings suggest that if the Tanzanian government continues to use a mixed public–private model to distribute ITNs, increasing the consumer subsidy alone will not dramatically improve ITN coverage. A concerted effort is required including an increase in the subsidy amount, attention to income growth for poor households, increases in women's and girls' education levels, and expansion of the retail ITN distribution network. Use of a catch-up campaign to distribute free ITNs would increase coverage but raises questions about the effect of households' long-term purchase decisions for ITNs.

Keywords Malaria, insecticide-treated nets, vouchers, demand elasticity

KEY MESSAGES

- The small price elasticity of demand for insecticide-treated nets in Tanzania means that increased consumer subsidies alone will not substantially improve net coverage. Similarly, income growth cannot be expected to induce large increases in net coverage.
- If the Government of Tanzania continues to employ a public–private partnership to distribute nets, a concerted effort on several fronts is required to increase net coverage, including an increase in the current subsidy, income growth promotion and an expansion of commercial distribution outlets for nets.

Introduction

Malaria kills over 800 000 African children each year (Rowe *et al*. 2006) and poses a health threat to millions of adults and children. Insecticide-treated bednets (ITNs) are an effective tool for reducing malaria exposure (Lengeler 2004) and international health organizations have recently agreed to an 80% ITN coverage target for pregnant women and infants in affected countries by 2010 (Roll Back Malaria Partnership 2005). Unfortunately, this target remains a distant reality throughout sub-Saharan Africa (UNICEF 2007; WHO 2008), though substantial improvements in coverage have occurred in some settings following free distribution campaigns (CDC 2006; Thwing *et al*. 2008).

Substantial disagreement remains about how best to distribute ITNs (Lengeler *et al*. 2007; Lines *et al*. 2008). Possible schemes range from widespread free delivery (Curtis *et al*. 2003; Maxwell *et al*. 2006; Noor *et al*. 2007; Teklehaimanot *et al*. 2007) to subsidized distribution via the commercial sector (Armstrong Schellenberg *et al*. 1999; Hanson *et al*. 2003; Magesa *et al*. 2005; Webster *et al*. 2005). While this study does not intend to resolve this controversy, one vital component absent from the discussion is accurate and nationally representative information regarding household preferences for ITNs. The limited available evidence to date on ITN demand comes from contingent valuation studies or limited geographic samples (Onwujekwe *et al*. 2003; Onwujekwe and Uzochukwu 2004; Onwujekwe *et al*. 2005; Mujinja 2006; Cohen and Dupas 2010), which decrease their relevance in guiding national ITN policies.

This study helps fill the void regarding household preferences for ITNs by estimating ITN demand throughout Tanzania between 2004 and 2006. In September 2004, Tanzania launched a national ITN promotion programme, the Tanzanian National Voucher Scheme (TNVS), which provides subsidized ITNs to all pregnant women who visit antenatal clinics. Data from the TNVS are used to estimate ITN demand elasticity with respect to ITN prices and household income. The impact of free ITN distribution on short-term ITN purchases is also derived.

Methods and data

The TNVS began in October 2004 and by May 2006 reached all 21 regions in Tanzania's mainland (Magesa *et al*. 2005; Hanson *et al*. 2007; Hanson *et al*. 2008). The programme provides an ITN subsidy to pregnant women using a voucher system. Women who attend antenatal clinics receive a discount voucher worth 2750 Tanzanian shillings (TSh) (approximately US$2.29) towards the purchase of an ITN. The TNVS supplies vouchers to the clinics and trains clinic staff in how to distribute the vouchers. It also recruits shopkeepers near each clinic for retail ITN distribution. Voucher recipients purchase ITNs by providing a 'top-up' payment to the retailer equal to the gap between the voucher amount and the retail price, which generally ranges from 3000 to 5000 TSh. Consequently, the top-up varies with local market conditions and ITN characteristics such as size, brand and colour. Shopkeepers exchange their vouchers with ITN wholesalers for new ITN stock, wholesalers in turn exchange their vouchers with manufacturers for new ITN stock and the TNVS pays the manufacturers 2750 TSh per voucher.

The programme therefore is an example of a 'public–private partnership', with important contributions from the national government (programme management by the National Malaria Control Programme together with technical support from the Swiss Tropical Institute), routine public and non-government health services (distribution of vouchers to women), implementing non-government organizations (the logistics contractor, MEDA, and training and promotion contractors CARE and World Vision), the commercial private sector (ITN manufacturers and retail distributors) and other organizations that contribute to the broader ITN strategy by creating an enabling environment (e.g. Population Services International through the SMARNET project). Between September 2004 and July 2006, the antenatal clinics distributed over 1 million vouchers to pregnant women throughout Tanzania. A detailed tracking study suggests that nearly all these vouchers reached their intended targets with little misuse (Nathan *et al*. 2007). The effect of the voucher scheme on ITN coverage of target groups is reported elsewhere (Hanson *et al*. 2009).

In early 2007 the environment surrounding the voucher programme changed considerably (Mulligan *et al*. 2008; Hanson *et al*. 2009). The TNVS introduced two changes to its operations by increasing the voucher amount to 3250 TSh (which only partly compensated for higher retail ITN prices, arising in part from oil price increases) and adding a new voucher for infants. In addition, the National Malaria Control Programme launched a national 'catch-up' campaign in late 2008 to distribute free ITNs to all children under 5 years old. During this same period, long lasting insecticidal nets (LLINs) began to be distributed in Tanzania. Because all these changes would confound accurate demand estimation, this study focuses exclusively on the initial period of TNVS operations between 2004 and 2006, and only measures preferences for conventional ITNs that are bundled with an insecticide kit.

The main data source for this study is the 2006 TNVS Monitoring and Evaluation Survey. The survey covers over 6000 households in 21 districts in Tanzania, which comprise approximately one-sixth of all districts nationwide. Districts were randomly selected after stratifying by TNVS launch date, with seven districts from the 'early' launch stratum, seven from among the 'middle' launch districts and seven from the 'late' launch districts. The survey was implemented between June and August 2006. Full details are available in Hanson *et al*. (2008). Ethical approval for the study was provided by the Institutional Review Board of the Ifakara Health Institute, the Tanzania National Medical Research Coordination Committee, and the ethics committee of the London School of Hygiene and Tropical Medicine.

During its first 2 years of operation, the TNVS greatly affected the ITN environment in Tanzania (Hanson *et al*. 2009). The household monitoring survey reveals that 70% of all pregnant women in 2006 received a voucher, with no statistically significant differences in voucher coverage due to clients' socio-economic status (Hanson *et al*. 2007). Routine monitoring records indicate that voucher redemption nationally ranged from 80% to 82% throughout the period (Nick Brown, personal communication). Between 2005 and 2006 the share of households

owning any type of net grew from 44% to 57% and household ownership of at least one ITN increased from 18% to 29%. The percentage of pregnant women sleeping under an ITN increased from 11% to 18% and the percentage of infants sleeping under an ITN increased from 16% to 28%. However, ITN coverage indicators for the poorest households are well below these national averages.

The specific sample for this study includes women from the survey households that received a voucher and also reported knowing about the TNVS, which covered 96% of all voucher recipients. Because this study does not aim to measure the impact of TNVS marketing efforts on voucher use, a homogeneous sample is needed regarding voucher recipients' knowledge of the TNVS. Women reporting that they paid clinic staff for their voucher, comprising 6% of all voucher recipients, are also excluded. These cases likely occurred due to mistakes or misuse by clinic staff or because respondents incorrectly gave the top-up paid to the retailer when asked how much they paid for their voucher.[1] The final sample contained complete information for 529 voucher recipients, of which 83% used their voucher to purchase an ITN.[2]

Following basic micro-economic theory and previous studies of health input demand (Akin *et al*. 1986; Cropper *et al*. 2004), a voucher recipient's demand for ITNs depends on her household's income level, the ITN price (i.e. top-up amount), her demographic situation, her general preference set and exogenous variables that potentially affect her household's health status. For this study, the dependent variable in the demand equation is the voucher recipient's decision to buy an ITN, which is a binary variable equal to 1 if she bought an ITN and otherwise equal to 0. Because the dependent variable is binary, demand estimation requires a logit or probit model, where the predicted value of the estimated equation equals the probability that a woman uses her voucher to buy an ITN. Provided that the estimated equation and relevant explanatory variables show statistical significance, they can be used to calculate demand elasticities for price, income and other factors.

ITN top-up amounts come from an audit of randomly selected retailers in 21 districts throughout Tanzania between April and September 2005 (Mulligan *et al*. 2007). These districts match those chosen for the TNVS household survey. The top-up amounts used in the regression estimate are the district average retail price for each voucher recipient minus the voucher amount. Note that retail prices naturally vary with local market conditions, including transportation costs over long distances and difficult terrain. Because the top-up amount directly follows the retail price, average retail prices minus 2750 TSh proxy the required top-up for each district's voucher recipients.

Retailers in Tanzania typically sell a combination of small, medium and large nets, which raises a question regarding the correct price for demand estimation. The household survey shows that medium-sized nets comprised the lion's share of voucher purchases, at 39% in 2005 and 45% in 2006 (Hanson *et al*. 2007: Table 10). Moreover, there is evidence from the household surveys that nets purchased with vouchers were on average larger than non-voucher nets, suggesting that vouchers allow some households to 'scale up' in size, rather than automatically choosing the small net. In light of both observations, the average price of a medium-sized net in each district is used to proxy the district's representative retail ITN price.[3] To correctly aggregate prices using disparate size nets, the price data are first normalized to a square foot equivalent and then multiplied by the area of a medium-sized net (24 square feet). The complete sample contains data from 352 ITN retailers and 481 observed prices.[4] Figure 1 shows the mean and standard deviation of the estimated top-up values for both the overall sample and for each district.

It is unknown *a priori* whether the district-wide ITN prices simply reflect other conditions within each district such as overall development and poverty levels, therefore potentially biasing the estimated price coefficient, or whether they reflect market conditions that are quasi-random. While the latter assumption is employed here to identify the price effect in the demand estimation, one method to test this assumption is to regress the district-wide prices against district indicators of overall economic development. Appendix A provides details of this regression estimate, with the results suggesting that district-wide ITN prices are independent of general economic conditions.

An index computed for the 2006 TNVS monitoring and evaluation report measures households' socio-economic status and acts as a proxy indicator for household consumption (Hanson *et al*. 2007). The index includes various household assets, the education status of the household head, the type of roofing materials of the residence, whether the household owned or rented its residence, access to electricity and type of sanitation system. These variables are aggregated using principal components analysis, with the resulting index divided into quintiles denoting socio-economic status.

In addition to the aforementioned factors, a potentially important ITN demand variable is whether the voucher recipient's household received a free ITN. It is possible that receipt of a free ITN stimulates additional ITN purchases as household members become accustomed to their use and subsequent benefits. On the other hand, voucher recipients may substitute the free ITN for a planned ITN purchase in the short-term. Moreover, receipt of a free ITN might create an expectation that ITNs are government-provided goods, which would decrease households' future willingness to pay. Another possibility is that receipt of a free ITN does not affect long-term ITN demand since the household simply replaces the free ITN with a purchased ITN after the free unit deteriorates.

This study estimates the impact of free ITN receipt on the short-term ITN purchase decisions of voucher recipients. The data reveal which households in Nachingwea, Tandahimba and Rufiji districts received a free ITN as part of broad vaccination campaigns in 2005 (Skarbinski *et al*. 2007; Khatib *et al*. 2008). A separate binary variable in the demand equation equals 1 if the free ITN arrived in the voucher recipient's household prior to her delivery date. In addition, a small number of voucher recipients in other districts reported that their household received a free ITN from various sources. The binary variable is similarly constructed for these women. While it is possible that these households received their free ITNs because of their specific socio-economic condition, Appendix B suggests that households receiving free ITNs do not differ in terms of their socio-economic status from households that did not receive free ITNs.

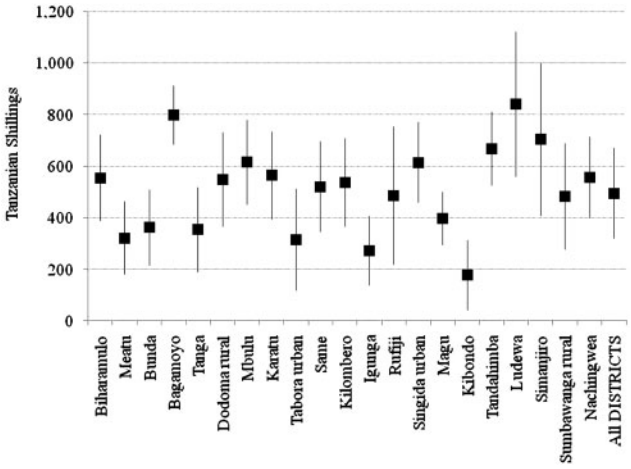

Figure 1 Average top-up amounts for voucher-based ITN purchases, by district. *Source*: See PRICE in Table 1. *Note*: The squares represent the mean district top-up amount and the vertical lines represent the standard deviation within that district.

Due to the fact that the price data are district-wide and the ITN demand data describe individual voucher recipients, it is incorrect to employ an ordinary logit or probit estimation procedure. Rather, the appropriate model is a generalized estimating equation (GEE) (Zeger and Liang 1986; Ballinger 2004). In short, the GEE model allows for a binary dependent variable but also accommodates cluster-wide explanatory variables such as the district prices in this study. The GEE model incorporates the fact that observations within each cluster are potentially correlated and makes the appropriate adjustments to the estimated standard errors of the coefficients.

Results

Table 1 summarizes the data used to estimate the ITN demand equation while Table 2 contains the corresponding regression estimates. The estimated signs and significance of the coefficients on individual explanatory variables match expectations from economic theory. Women from households with higher socio-economic status show a higher probability of buying an ITN, which is expected for normal consumer goods. Higher top-up amounts reduce the probability that the voucher recipient buys an ITN, which is the expected negative relationship between price and quantity demanded. The estimated coefficient on receipt of a free ITN is significant and negative, showing that free ITNs negatively affect short-term ITN purchase decisions for voucher recipients. Two other key variables worth noting are mothers' primary education and the density of TNVS retailers, which both positively affect ITN demand.

Table 2 also shows the marginal impact of each variable on the probability that the voucher recipient buys an ITN. For the continuous explanatory variables, this value is straightforward to interpret. For the binary explanatory variables, the exponential function is first applied to the estimated coefficient. The resulting number equals the binary variable's effect on the odds ratio, which is the probability of an ITN purchase divided by the probability of no purchase (Liao 1994). For example, the estimated coefficient on the highest quintile shows that the odds of a woman from that subgroup buying an ITN is 4.09 times that of a woman from the bottom quintile.

It is possible that ITN prices and free ITNs have a different effect on the demand of women from the poorest households compared with those from less poor households. Poor women might show a relatively large demand response to ITN price changes since the top-up payment comprises a greater share of total household spending. Similarly, poor women's demand response to a free ITN may differ from less poor women, though the predicted response is not obvious. These two questions are explored by conducting separate demand estimates for the lowest two and top two quintiles.[5] The results show that the marginal impact of price on the purchase decisions of poor women is twice that of less poor women. However, the impact of free ITNs on ITN demand does not appreciably differ by socio-economic status.

Table 2 provides information to compute demand elasticities, which show the percentage change in ITNs purchased for a 1% change in the explanatory variable. For the continuous explanatory variables, elasticities come from the marginal probability effects in column four, the sample mean of the respective variable and the corresponding purchase probability. Looking at ITN prices, the demand elasticity (−0.125) equals the marginal probability effect (−0.0002) times the ratio of the mean top-up (479.2 TSh) to the mean purchase probability (0.828). For the income elasticities of demand, data from the World Bank (2007) show the share of gross domestic product (GDP) that households earn in each expenditure quintile. Applying these shares to national GDP yields the total GDP earned by each quintile. Dividing each quintile's total income by one-fifth of the total population gives the mean GDP per capita for households in each quintile. The percentage change in income between each quintile is then compared with the predicted percentage change in the number of ITNs purchased per 100 voucher recipients at each expenditure quintile.

Both the price and income elasticities of demand are very small, while receipt of a free ITN moderately reduces a woman's probability of buying an ITN. Overall price elasticity of demand equals −0.125, and while larger for poor households, it is still highly inelastic (−0.321). One important caveat regarding the price elasticity is that the estimate reflects demand behaviour under the subsidized price scheme. The price elasticity for unsubsidized ITNs may differ and is quite likely more elastic, but its estimation lies beyond this study.[6] The estimated income elasticity of demand equals 0.46 for the poorest quintile and remains below 0.15 for the other quintiles. Free ITNs reduce the odds of a woman's ITN purchase by a factor of 0.28, which is equivalent to a decrease in the purchase probability from 0.83 to 0.56 for women in 'average' households and a decrease from 0.65 to 0.34 for women from the poorest quintile.

Discussion

The estimated demand elasticities obtained here compare favourably with previous studies that use either contingent valuation or experimental methods. Onwujekwe *et al*. (2004) find that when ITN prices are well below market equilibrium, price elasticity for ITNs in Nigeria ranges from −0.60 to −0.91

Table 1 Summary of variables used to estimate the ITN demand model

Variable name	Description	Sample mean	Sample standard deviation
BUY	Binary variable = 1 if the woman buys an ITN, otherwise = 0	0.828[a]	–
SES2	Binary variables indicating which socio-economic quintile the voucher recipient's household belongs to (SES1, the poorest, is the base quintile and not included in the regression)	0.195	–
SES3		0.221	–
SES4		0.265	–
SES5		0.200	–
PRICE	Average top-up paid for ITNs in the voucher recipient's district, in TSh[b]	479.2	151.7
RETAIL[c]	Ratio of TNVS participating retailers to participating antenatal clinics in the voucher recipient's district, as of June 2006	1.03	0.156
EDUC	Binary variable = 1 if the voucher recipient received a primary level education (minimum 7 years), otherwise = 0	0.681	–
FAMSIZE	Total number of people residing in the voucher recipient's household	6.34	2.75
FEMALEHH	Binary variable = 1 if no adult male resides in the voucher recipient's household, otherwise = 0	0.306	–
SOLECHILD	Binary variable = 1 if the voucher recipient has no other children under age 6 besides the voucher infant living with her, otherwise = 0	0.363	–
OTHERCHILDREN	Share of the voucher recipient's household comprised of children age 5 or less, multiplied by SOLECHILD	0.097	0.145
FREENET	Binary variable = 1 if the voucher recipient's household received a free ITN prior to the birth of her child, otherwise = 0	0.095	–
Sample size		529	

Source: TNVS monitoring and evaluation survey (Hanson *et al*. 2007), except for PRICE (Mulligan *et al*. 2007) and RETAIL.

[a]Voucher redemption rates for each quintile range from 64.6% (poorest) to 91.3% (least poor).

[b]Retail prices first normalized on a per square foot basis, averaged for each district, and then converted to the equivalent price of a medium-sized net (24 square feet).

[c]Data from Mennonite Economic Development Associates (MEDA), the TNVS logistics contractor.

across income categories. Income elasticities ranged from 0.26 to 0.52. Cohen and Dupas (2010) estimate the price elasticity for ITNs in Kenya at −0.37 when the subsidized ITN price is approximately US$0.25.

The low elasticity of demand for ITN prices shows that merely increasing consumer subsidies will do little to expand ITN coverage. The voucher increase in 2007 provides a working example. If ITN prices had followed the general inflation rate of 7% in 2007 (United Republic of Tanzania 2008), the voucher increase would have produced a 57% drop in the average real (inflation adjusted) top-up. However, the percentage change in the top-up multiplied by the price elasticity predicts a mere 7% corresponding increase in voucher recipients' ITN purchases, *ceteris paribus*. In reality, anecdotal evidence suggests that ITN prices outpaced inflation during that time, primarily due to large increases in world petroleum prices. Under this scenario the model predicts a decline in the purchase rate by voucher recipients in 2007, which is precisely what happened, from 83% in 2006 to 73% in 2007 (Marchant *et al*. 2008: Table 41).

The small income elasticities of demand suggest that economic growth alone will not lead to substantial increases in ITN coverage. If voucher recipients from the lowest quintile experience 10% income growth, they will increase their ITN purchases by only 4.6%. Similar income growth for wealthier households will produce even smaller increases in ITN purchases as per their respective income elasticities. Furthermore, the current global recession raises doubts about whether such income growth will occur anytime soon.

The finding that free ITNs reduce voucher recipients' short-term ITN purchases is important to consider but also warrants additional investigation. In the short term, reduced purchases by voucher recipients during a free distribution campaign do not diminish overall ITN coverage since the free ITNs easily exceed the decline in purchases. However, three unresolved questions are: (1) whether short-term purchase reductions by voucher recipients cause a decline in the number of participating TNVS retailers; (2) whether free ITNs similarly affect unsubsidized ITN purchases in the short term (which could also have a second-order effect on the number of retailers); and (3) whether free ITNs affect both subsidized and unsubsidized ITN purchases over the long term.

Two variables in the estimated demand model that should not be overlooked are the voucher recipient's education level and the density of ITN retailers in each district. While neither of these policy-related variables present immediate solutions for increasing ITN coverage, the evidence suggests a modest impact on ITN coverage of expanded education for women and girls. Similarly, expanding the number of participating ITN retailers will increase voucher redemption rates as women experience reduced travel costs and improved convenience when purchasing an ITN.

There are a number of potential limitations to this analysis. First, the strategy for identifying the price effect in the demand equation rests on the assumption that the variation in ITN prices is exogenous, and does not interact with other, unmeasured, influences on ITN purchase decisions. We investigated

Table 2 Logit GEE estimates of the ITN demand model. Dependent variable = BUY

Variable name	Estimated coefficient	*P*-value	Marginal probability effect	Elasticity
SES2[a]	0.839**	0.021	2.31[b]	0.459
SES3[a]	0.839**	0.021	2.31[b]	0.000
SES4	1.103***	0.000	3.01[b]	0.140
SES5	1.408***	0.000	4.09[b]	0.067
PRICE	−0.002**	0.015	−0.0002[c]	−0.125[d]
RETAIL	2.208***	0.000	0.255[c]	0.318
FAMSIZE	0.091**	0.011	0.011[c]	0.080
EDUC	0.541**	0.002	1.72[b]	–
FEMALEHH	0.537**	0.001	1.71[b]	–
FREENET	−1.268***	0.000	0.282[b]	–
SOLECHILD	1.265***	0.000	3.57[b]	–
OTHERCHILDREN	−4.342***	0.000	−0.502[c]	−0.058
Intercept	−1.487*	0.056	–	–
Correlation coefficient within districts[e]	0.012			
Kappa indicator of fit[f]	0.134			
Sample size	529			

Notes:

*Significantly different from zero at the 90% confidence level.

**Significantly different from zero at the 95% confidence level.

***Significantly different from zero at the 99% confidence level.

[a]A preliminary regression showed that the coefficients on SES2 and SES3 were not significantly different. Hence, the two coefficients were constrained to be equal in this estimation. Details are available upon request.

[b]Equals the exponential function applied to the estimated coefficient, which gives the multiplicative change in the odds ratio when the binary variable changes from zero to one (Liao 1994).

[c]Equals $\delta \text{Prob}(\text{BUY}=1)/\delta x_j$, where x_j is the jth continuous explanatory variable. Computed at the sample means.

[d]When estimated separately, the price elasticity equals −0.321 for the bottom two quintiles and −0.083 for the top two quintiles.

[e]Following Ballinger (2004), an 'exchangeable' covariance structure is imposed in the GEE model where the intra-district correlations are assumed identical across districts.

[f]The Kappa indicator of goodness-of-fit for GEE estimation (Williamson *et al*. 2003) ranges from 0 to 1, with 1 showing perfect fit.

one possible set of influences by regressing ITN prices on various measures of district-level socio-economic development and found no relationship. However, to the extent that other, unobservable factors such as access to credit are positively correlated with both price and purchasing decisions, the estimated price coefficient could be biased upward. A second hypothesis, suggested by the data on the number of ITN retailers per clinic, is that retailers have monopoly power and might therefore practise price discrimination according to specific customers' ability to pay. From the available data it is impossible to know the extent of price discrimination practised by TNVS retailers. Moreover, it is unclear how price discrimination would affect the price elasticity estimate. A relatively small top-up for poorer women *ceteris paribus* would suggest an upward bias to their elasticity estimate. However, poorer women also have a lower probability of buying an ITN, thus making the direction of the possible bias impossible to predict. Similar arguments apply to less poor women who might pay a relatively large top-up. The fact that our price elasticity estimates are consistent with others in the literature provides some assurance that these biases are not large, but they cannot be ruled out.

Secondly, interpreting the 'FREENET' coefficient in the demand model as measuring how free ITNs affect short-term ITN purchases rests on the assumption that the choice of districts to receive free ITNs was random and not targeted towards the poorest households. To the extent that unobservable factors affecting ITN purchases are also correlated with free ITN receipts, the estimated coefficient may be biased. While the findings suggest no correlation between household socio-economic status and whether or not the household received a free ITN, the number of free ITN households was relatively small, which may have restricted the power to detect a significant difference between these groups.

Conclusion and implications for ITN policy

This study finds that under the recent voucher-based distribution scheme for ITNs in Tanzania, both price and income elasticities of demand for ITNs are highly inelastic. As a result, a single programme change designed to increase ITN coverage, such as increased consumer subsidies, will not substantially improve coverage rates. However, because the voucher recipient's top-up payment inversely affects ITN purchases, with poor households showing a relatively large effect, policy-makers should ensure that the voucher at least keeps pace with the retail price of ITNs. The evidence also shows that receiving a free ITN decreases short-term ITN purchases for voucher recipients. The effects of free ITNs on unsubsidized and long-term ITN purchases are unknown.

These findings have important implications for ITN delivery strategy in Tanzania and elsewhere. The Government of Tanzania plans to continue to combine intermittent free ITN campaigns ('catch-up') with routine distribution through antenatal and child health services using the voucher scheme. Our results suggest that a number of steps are needed for the voucher scheme to continue contributing towards increased and sustained ITN coverage. These include continual adjustment of the subsidy so that real top-up amounts are either stable or decreasing, attention to overall income growth for the poorest households, improving general education levels for women and girls, and expanding the number of ITN retailers.

In addition, these findings provide some evidence about the interactions between two delivery systems in a 'pluralistic' system which tries to combine 'catch-up' with 'keep-up', and suggest some hypotheses for further study in this new delivery context. The finding that those who receive a free ITN are less likely to purchase a subsidized ITN using the voucher scheme has two possible implications. On the one hand, this finding could suggest that free ITNs dampen demand for ITNs provided through the retail sector, even if these are highly subsidized. This could potentially have negative effects on the commercial supply of ITNs. How one interprets this finding greatly depends on perception of the credibility of donor commitment to continue

funding ITNs through campaigns and to provide sufficient free ITNs to achieve 'universal coverage'. On the other hand, the finding that those who have a net already are less likely to purchase a new net in the short-term may reflect a fully reasonable strategy of households waiting until the free net is worn out before replacing it with a voucher net. Further research is required to determine whether it is possible to combine free nets delivered through mass campaigns with a system which relies on the commercial sector to distribute nets, and to determine whether the coverage achieved through this combined system is more sustainable than that which any one system can achieve on its own.

Acknowledgements

The authors wish to thank two anonymous reviewers for their helpful comments and suggestions. However, the authors bear full responsibility for the content herein.

Funding

The collection of data used in this study was funded by the Ministry of Health and Social Welfare, Government of Tanzania, though a grant from the Global Fund to Fight AIDS, TB and Malaria, the Gates Malaria Partnership, the UK Department for International Development and the Royal Netherlands Embassy (through grants to Population Services International). CG's contribution was funded by Mennonite Economic Development Associates and Eastern Mennonite University.

Endnotes

[1] For those retailers offering multiple net sizes for sale at the time of the retail survey, an average of the price per square foot is first computed for the individual retailer.

[2] An alternative method is to use the minimum net price for each district in the demand equation. While the retailer survey data do not allow construction of each district's representative minimum price, demand estimation using small nets as the district average price showed virtually identical results compared with using the price of medium-sized nets. These results are available upon request.

[3] The redemption rate for the demand sample matches the redemption rate from the nationally representative survey (Hanson *et al*. 2007).

[4] The latter explanation appears correct since 31 of 34 voucher recipients who claim to have paid for their voucher also stated that the amount paid for the voucher equalled the exact amount paid to buy the ITN.

[5] Detailed results are available upon request.

[6] If the ITN demand equation is linear throughout, movement to a higher price will eventually show an elastic demand response. However, no assumption about the overall shape of the ITN demand equation is imposed here.

References

Akin JS, Griffin CC, Guilkey DK, Popkin BM. 1986. The demand for primary health care services in the Bicol Region of the Philippines. *Economic Development and Cultural Change* **34**: 755–82.

Armstrong Schellenberg J, Abdulla S, Minja H *et al.* 1999. KINET: a social marketing programme of treated nets and net treatment for malaria control in Tanzania, with evaluation of child health and long-term survival. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **93**: 225–31.

Ballinger G. 2004. Using generalized estimating equations for longitudinal analysis. *Organizational Research Methods* **7**: 127–50.

Centers for Disease Control (CDC). 2006. Distribution of insecticide-treated bednets during a polio immunization campaign—Niger, 2005. *Morbidity and Mortality Weekly Report* **55**: 913–6.

Cohen J, Dupas P. 2010. Free distribution or cost-sharing? Evidence from a randomized malaria prevention experiment. *Quarterly Journal of Economics* **125**: 1–45.

Cropper ML, Haile M, Lampietti J, Poulos C, Whittington D. 2004. The demand for a malaria vaccine: evidence from Ethiopia. *Journal of Development Economics* **75**: 303–18.

Curtis C, Maxwell C, Lemgne M *et al.* 2003. Scaling-up coverage with insecticide-treated nets against malaria in Africa: who should pay? *Lancet Infectious Diseases* **3**: 304–7.

Hanson K, Kikumbih N, Armstrong Schellenberg J *et al.* 2003. Cost-effectiveness of social marketing of insecticide-treated nets for malaria control in the United Republic of Tanzania. *Bulletin of the World Health Organization* **81**: 269–76.

Hanson K, Marchant T, Mponda H, Nathan R, Bruce J. 2007. *Monitoring and evaluation of the TNVS: report on 2006 TNVS household, facility services and facility users surveys (a comparison between baseline and 12 month follow-up)*. Dar es Salaam and London: Ifakara Health Research and Development Centre, London School of Hygiene and Tropical Medicine.

Hanson K, Marchant T, Nathan R *et al.* 2009. A national voucher programme for insecticide treated nets in Tanzania: effects on household ownership and use among target groups after three years of implementation. *British Medical Journal* **338**: b2434.

Hanson K, Nathan R, Marchant T *et al.* 2008. Vouchers for scaling up insecticide-treated nets in Tanzania: methods for monitoring and evaluation of a national health system intervention. *BMC Public Health* **8**: 205.

Khatib RA, Kileen GF, Abdulla SMK *et al.* 2008. Markets, voucher subsidies and free nets combine to achieve high bednet coverage in rural Tanzania. *Malaria Journal* **7**: 98.

Lengeler C. 2004. Insecticide-treated bed nets and curtains for preventing malaria. *Cochrane Database of Systematic Reviews* (2) CD000363.

Lengeler C, Grabowsky M, Mcguire D, de Savigny D. 2007. Quick wins versus sustainability: options for the upscaling of insecticide-treated nets. *American Journal of Tropical Medicine and Hygiene* **7**: 222–6.

Liao TF. 1994. *Interpreting Probability Models*. London: Sage Publications.

Lines J, Schapira A, Smith T. 2008. Tackling malaria today. *British Medical Journal* **337**: a869.

Magesa SM, Lengeler C, de Savigny D *et al.* 2005. Creating an 'enabling environment' for taking insecticide treated nets to national scale: the Tanzanian experience. *Malaria Journal* **4**: 34.

Marchant T, Bruce J, Nathan R *et al.* 2008. *Monitoring and evaluation of the TNVS. Report on 2007 TNVS household, facility services and facility users surveys*. Dar es Salaam and London: Ifakara Health Research and Development Centre and London School of Hygiene and Tropical Medicine.

Maxwell CA, Rwegoshora RT, Magesa SM, Curtis CF. 2006. Comparison of coverage with insecticide-treated nets in a Tanzanian town and villages where nets and insecticide are either marketed or provided free of charge. *Malaria Journal* **5**: 44.

Mujinja PG. 2006. Exploring determinants of consumer preferences and willingness-to-pay for insecticides treated bednets before intervention in a poor rural Tanzania. *East African Journal of Public Health* **3**: 17–23.

Mulligan J, Ebenezeri S, Mtwara E, Stephen G, Hanson K. 2007. *Report on second round of retail census of the Tanzanian National Voucher Scheme*. Dar es Salaam and London: Ifakara Health Research and Development Centre and London School of Hygiene and Tropical Medicine.

Mulligan J, Yukich J, Hanson K. 2008. Costs and effects of the Tanzanian National Voucher Scheme for insecticide-treated nets. *Malaria Journal* **7**: 32.

Nathan R, Marchant T, Sedekia Y, Hanson K, Mponda H. 2007. *Tanzania National Voucher Scheme: Report on 2006/7 Voucher Tracking Study*. Dar es Salaam and London: Ifakara Health Research and Development Centre, London School of Hygiene and Tropical Medicine.

Noor AM, Amin AA, Akhwale WS, Snow RW. 2007. Increasing coverage and decreasing inequity in insecticide-treated bed net use among rural Kenyan children. *PLoS Medicine* **4**: e255.

Onwujekwe O, Hanson K, Fox-Rushby J. 2003. Who buys insecticide-treated nets? Implications for increasing coverage in Nigeria. *Health Policy and Planning* **18**: 279–89.

Onwujekwe O, Hanson K, Fox-Rushby J. 2004. Inequalities in purchase of mosquito nets and willingness to pay for insecticide treated nets in Nigeria: challenges for malaria control and interventions. *Malaria Journal* **3**: 6.

Onwujekwe O, Malik EM, Mustafa SH, Mnzava A. 2005. Socio-economic inequity in demand for insecticide-treated nets, in-door residual house spraying, larviciding and fogging in Sudan. *Malaria Journal* **4**: 62.

Onwujekwe O, Uzochukwu B. 2004. Stated and actual altruistic willingness to pay for insecticide-treated nets in Nigeria: validity of open-ended and binary with follow-up questions. *Health Economics* **13**: 477–92.

Roll Back Malaria Partnership. 2005. *Global Strategic Plan 2005–2015*. Online at: http://www.rollbackmalaria.org/forumV/docs/gsp_en.pdf, accessed 5 March 2008.

Rowe AK, Rowe SY, Snow RW *et al.* 2006. The burden of malaria mortality among African children in the year 2000. *International Journal of Epidemiology* **35**: 691–704.

Skarbinski J, Massaga JJ, Rowe AK, Kachur SP. 2007. Distribution of free untreated bednets bundled with insecticide via an integrated child health campaign in Lindi Region, Tanzania: lessons for future campaigns. *American Journal of Tropical Medicine and Hygiene* **76**: 1100–6.

Teklehaimanot A, Sachs JD, Curtis C. 2007. Malaria control needs mass distribution of insecticidal bednets. *The Lancet* **639**: 2143–6.

Thwing J, Hochberg N, Eng JV *et al.* 2008. Insecticide-treated net ownership and usage in Niger after a nationwide integrated campaign. *Tropical Medicine and International Health* **13**: 827–34.

United Nations Children's Fund (UNICEF). 2007. *Malaria and Children: Progress in Intervention Coverage*. Online at: http://www.unicef.org/health/files/Malaria_Oct6_for_web(1).pdf, accessed December 2008.

United Republic of Tanzania. 2005. *Tanzania Poverty and Human Development Report 2005*. Online at: http://www.repoa.or.tz/documents_storage/PHDR_2005_Prelim.pdf, accessed July 2009.

United Republic of Tanzania. 2008. *The Economic Survey 2007*. Online at: http://www.tanzania.go.tz/economicsurveyf.html, accessed July 2009.

Webster J, Lines J, Bruce J, Armstrong Schellenberg J, Hanson K. 2005. Which delivery systems reach the poor? A review of equity of coverage of ever-treated nets, never-treated nets, and immunization to reduce child mortality in Africa. *The Lancet* **5**: 709–17.

Williamson JM, Lin H-M, Barnhart HX. 2003. A classification statistic for GEE categorical response models. *Journal of Data Science* **1**: 149–65.

World Bank. 2007. *World Development Indicators*. Washington, DC: World Bank.

World Health Organization (WHO). 2008. *World Malaria Report 2008*. Online at: http://apps.who.int/malaria/wmr2008/malaria2008.pdf, accessed 5 July 2009.

Zeger S, Liang K. 1986. Longitudinal data analysis for discrete and continuous outcomes. *Biometrics* **42**: 121–30.

Appendix A

To explore whether district-wide ITN prices depend on other district characteristics, the district prices are regressed on three exogenous development indicators: poverty incidence, infant mortality and the primary school enrolment rate. Regression results are detailed in Appendix Table A.

Appendix B

To check whether the socio-economic status of households that received free ITNs differs from other households, the data

Appendix Table A

	Summary statistics Mean (standard deviation)	**Regression results** Estimated coefficient (*P*-value)
Dependent variable		
PRICE[a]	508.2 (167.4)	
Explanatory variable		
Poverty incidence[b]	39.5 (11.1)	−4.68 (0.183)
Infant mortality[c]	91.3 (23.5)	0.40 (0.801)
Primary school enrolment[d]	87.6 (13.9)	3.56 (0.195)
Intercept		344.29 (0.273)
R^2		0.20
Sample size	21	21

[a]See Table 1 for a description and source.

[b]Percentage of population in the district living below the poverty line, 2000/2001 (United Republic of Tanzania 2005).

[c]District infant mortality rate per 1000 live births, 2002 (United Republic of Tanzania 2005).

[d]District primary education net enrolment rate, 2004 (United Republic of Tanzania 2005).

are divided into two groups depending on whether they received a free ITN. The summary data are provided in Appendix Table B.

The chi-square statistic that tests for equal proportions of poor households in each group equals 1.66 (1 degree of freedom), with a *P*-value of 0.197. Hence, the null hypothesis that each group is comprised of comparable households cannot be rejected.

Appendix Table B

Household group	Number of households in first or second quintile	Total number of households	Proportion of total in first or second quintile
Did not receive a free ITN	149	483	0.31
Received a free ITN	19	46	0.41