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The economic cost to households of childhood malaria in Papua New Guinea: a focus on intra-country variation

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Background We compare direct and indirect household costs associated with malaria treatment for children <3 years in two provinces of Papua New Guinea. In particular, we explore the role of uncertainty around mean household costs and whether assuming a normal distribution for household costs limits the accuracy of any direct cost comparisons.

Methods Exit surveys were undertaken at inpatient and outpatient health facilities. In order to handle uncertainty and facilitate comparisons, parametric and non-parametric bootstrap methods were used to estimate direct and indirect costs at the individual data level. The inpatient and outpatient incremental costs from Madang and Maprik health facilities were compared and significant differences between provinces were identified.

Results Differences were noted between provinces for both inpatient and outpatient household costs. Total arithmetic mean costs for an outpatient malaria episode were US$7.54 in Madang and US$9.20 in Maprik. Total mean inpatient malaria episode costs were US$25.20 in Madang and US$14.08 in Maprik. As cost distributions were not normal, non-parametric bootstrap techniques were used for cost comparisons. Total household costs per outpatient episode of malaria were lower, although not significantly, in Maprik than in Madang (incremental cost of US$ −1.67; 95% CI −4.16, 0.31), while total household costs per inpatient episode were significantly higher in Madang than in Maprik (difference of US$11.16; 95% CI 5.47, 25.33). A difference was noted between provinces in the proportion of indirect costs in total household costs for an outpatient visit: 76% in Madang vs 94% in Maprik. The proportion for indirect costs associated with inpatient visits varied less: 63% in Madang vs 68% in Maprik.

Conclusions Intra-country differences need to be considered in estimating household costs for both outpatient and inpatient malaria treatment. Our findings suggest that it is important to recognize the impact of both direct and indirect costs on individuals' capacity to afford treatment. Certain indirect costs are difficult to measure accurately, particularly respondents' interpretations of their productive versus non-productive time. Despite this, exploring intra-country cost variation can provide important information to health policy makers.

Keywords Malaria, household costs, intra-country variation

KEY MESSAGES

- Significant intra-country household cost differences for malaria treatment in young children are present in Papua New Guinea.
- Exploring intra-country household cost differences may have compelling implications for health policy choices.
- Cost comparisons based on individual-level data should be undertaken using statistical methods which are able to shed light on the different sources of uncertainty.
- In household costs estimates it is important to recognize the impact of indirect costs and how they are measured, particularly in respondents' interpretation of their productive versus non-productive time.

Background

Malaria is the most common cause of illness and the second highest cause of mortality in Papua New Guinea (PNG), responsible for an estimated 1.5 million cases and almost 3000 deaths in 2006 (World Health Organization 2008). In certain areas malaria is the primary cause of death in children up to 4 years of age (Genton *et al*. 1995; World Health Organization 2008) and among the leading causes of hospital admissions (WHO Western Pacific Region 2004). Little is known about the economic burden this may place on households who seek treatment for children with suspected malaria.

This study aims to estimate and compare household costs for malaria treatment in children aged <3 years in two areas of PNG. Household costs are excluded in many economic evaluations, even though there is plenty of evidence to show the significant economic costs malaria places on households both directly, through out-of-pocket payments, and indirectly, through productivity lost (Asenso-Okyere and Dzator 1997; Konradsen *et al*. 1997; Deressa *et al*. 2007). There may, however, be good methodological and practical reasons for the lack of household cost data (Olsen and Richardson 1999; Tan-Torres *et al*. 2003). For example, including the indirect economic impact of malaria in the form of potential earnings forgone of patients and unpaid carers is controversial given the lack of consensus on which valuation method to use (Glied 1996; Su *et al*. 2007).

Omitting household costs fails to recognize that the cost incurred by an end user is one of the primary drivers in determining whether or not treatment will be sought. In a recent study in south-central Vietnam an episode of malaria was estimated to cost the patient's household an average of US$11.79 (in 2005 prices), almost 14% of the household's monthly income estimated in the same study (Morel *et al*. 2008). In several Nigerian communities where malaria is holo-endemic, the cost to households of treating malaria accounted for almost 50% of curative health care costs incurred by the households (Onwujekwe *et al*. 2000).

The need to better understand household costs for malaria treatment in PNG is crucial. High, moreover catastrophic, health expenditures have been shown to decrease utilization, particularly amongst the poorest sections of the population (Xu *et al*. 2003; Lagarde and Palmer 2008). In PNG this issue is all the more relevant as the cost of obtaining health services varies between regions. For example, one of the primary reasons for the regional differences is the lack of a government policy on the charges imposed by health facilities for the services they provide. Second, distance from health facilities has been shown to affect treatment-seeking choices in PNG (Muller *et al*. 1998; Davy *et al*. 2010). Therefore, costs associated with travelling to a health service, namely transportation costs and the value of time lost for treatment seeking, should be considered as key variables in health policy decision-making in the country.

Having recognized the importance of reporting household treatment cost, it is also important to consider how these costs are analysed. While the mean cost of treatments is of importance, there is a danger that decision-makers may place too much emphasis on results presented as point estimates in economic evaluations, without recognizing the uncertainty attached to these figures. Therefore, when patient-level data are available there is increasing recognition of the importance of providing confidence intervals of cost estimates in order to present the degree of uncertainty surrounding the estimate of treatment household costs (Altman *et al*. 1983; Thompson and Barber 2000).

In this paper we use both a parametric and a non-parametric bootstrap approach to handle uncertainty surrounding household cost estimates based on individual-level information collected from a sample of malaria patients. Because of the well-known issue of positive skewness of cost distributions, the calculation of confidence intervals presents some difficulties (Rutten-van Molken *et al*. 1994). In particular, parametric methods that rely on the normality of distributions are likely to be inadequate for cost comparisons (Zhou *et al*. 1997a; Zhou *et al*. 1997b). The presence of a few high values far from the majority of data cannot be ignored but at the same time could warp estimates and comparisons. Mean values inferred from skewed cost distribution with parametric methods such as t-test, based on the assumption of an underlying normal distribution, may not reflect the true household costs mean existing in the population; this is especially true when sample sizes are small and the central limit theory[1] does not apply. Moreover, log transformation of variables for overcoming normality problems or the use of a non-parametric test, such as Mann–Whitney, are not employed either, due to their difficulty in interpreting findings and interest in median instead of mean measures (Briggs and Gray 1998).

This paper compares direct and indirect household costs associated with malaria treatment in children aged <3 years in two provinces of PNG using two different approaches to reflect cost uncertainty. Because of the diverse intra-country geographical, cultural and health system differences, household costs are likely to be different (Davy *et al*. 2010). Intra-country cost variation is rarely presented as part of cost and cost-effectiveness results (Brooker *et al*. 2008), though a lack of understanding about the variation of costs (both to providers and households) can limit the success of efficiently and effectively scaling up interventions within and across countries (Goeree *et al*. 2007). To our knowledge, this is the first paper to analyse intra-country cost variations from a household cost perspective.

Methods

Study area and population

PNG is located in the southwestern Pacific Ocean. It occupies the eastern half of the island of New Guinea and includes numerous offshore islands (the western portion of the island is a part of the Indonesian provinces of Papua and West Papua) (US Department of State 2010). PNG is divided into 19 provinces, with over 800 indigenous language groups living in diverse geographical contexts (SIL International 2005). Malaria is highly endemic and comparatively stable in coastal areas but less stable in the Highlands regions, which are prone to epidemics (World Health Organization 2009).

This study aims to understand what factors drive the differences in household costs between two study sites of PNG which are geographically, culturally and linguistically different. The first of the two sites encompasses an area within or immediately adjacent to the provincial capital of Madang. The township Madang has about 35 000 inhabitants and has an economy partly supported by tourism. Malaria in Madang is hyperendemic with limited seasonality (Cattani *et al*. 1986).

The second study site is situated near the local administrative centre in Maprik, which is approximately 70 km inland from the nearest provincial capital of the East Sepik Province, Wewak. In terms of number of inhabitants, the township of Maprik is about seven times smaller than Madang with an economy driven by agriculture and local trade. Malaria in this study site has traditionally been holo-endemic with high transmission all year round. The two areas are characterized by the presence of both *Plasmodium falciparum* and *vivax* species of malaria parasite.

Four primary health care facilities in each of the two study sites were chosen to ensure that information was obtained from all health facility levels operating within both urban ($n = 2$) and rural areas ($n = 2$): hospital, health centre, sub-health centre and aid post. All health centres were government owned except for one, which was operated by the Catholic Church. In PNG the Department of Health is responsible for overall management of all primary health care facilities. This includes the development and implementation of health policies and standard guidelines, health planning, technical advice and the provision of specialist medical equipment and pharmaceutical supplies. They are also responsible for overseeing and registering the health professionals who work within the facilities, although many of the health professionals are trained by church-run training facilities. The government provides funding or subsidies to each facility based on type, size and location, although how these subsidies are actually spent is not known (Hauck *et al*. 2005).

In addition, user fees are payable at many of the health care facilities, although each health facility decides if and how much should be charged as there is no government policy on this.

Data collection

The study was designed to capture both the direct and the indirect costs to households seeking treatment for a child <3 years of age who presented with symptoms of malaria at one of the participating inpatient or outpatient health care facilities. Confirmed and presumptive malaria episodes were included because laboratory tests and rapid diagnostic tests are often not available in PNG, and therefore symptoms of malaria, including fever, are considered to be a strong indication of a malaria episode (Muller *et al*. 2003).

Prior to commencing, a full study, protocol and survey tool was submitted to and approved by both the PNG Institute of Medical (IMR) Research Internal Review Board and the PNG Medical Advisory Committee. To ensure the highest possible ethical and operational research standards, the study was also conducted in accordance with the Good Clinical Practice E6 Guidelines (ICH Expert Working Group 1996).

Using a closed-ended questionnaire, data were collected between June 2007 and March 2008 from carers with children attending outpatient facilities and also those admitted for a minimum of 24 hours to an inpatient facility with confirmed or presumptive malaria. All children presenting at the health facilities with presumed malaria were eligible for inclusion. The questionnaire was administered by trained research centre staff while at the health facility, at a time most convenient for the carer and the patient towards the end of their visit. Once the study had been fully explained to the carer, informed consent was obtained and the questionnaire administered. In a bid to capture the full costs of the episode to date, data were collected on the cost of obtaining treatment from not only the current health care provider but also costs associated with any other treatment, which had previously been sought for that episode of malaria since the episode was perceived by the carer to have started.

The questionnaire included questions associated with both direct and indirect costs. Direct costs reflected expenditure on drugs, facility and transport charges. Indirect costs reflected the time taken to care for a sick child and the subsequent loss of salary (income loss) or productivity forgone (welfare loss). Where there was a productivity loss but no financial loss, in other words no salary reported, the opportunity costs associated with looking after the sick child were modelled based on International Labour Organization (ILO) data. The legal minimum wage in PNG according to ILO was of 0.94 Kina per hour in 2007 (ILO, December 2008), the equivalent of US$0.36, and this was then multiplied by the reported time the primary carer spent tending to the child with malaria. Direct costs were collected for the primary care giver and any other carers from the household reporting out-of-pocket expenditure related to the malaria episode. Indirect costs of only the primary carer were reported. Costs are presented in US$ 2007; exchange rate Kina/US$ = 0.39 (OANDA 2007).

Data analysis

The analysis undertaken partly follows the methodology reviewed in Briggs and Gray (1998) and reported in Lord and Asante (1999), in which non-parametric bootstrap methods, opposed to parametric methods, are used to make comparison between two groups of patients. Specifically, the estimates of incremental costs are the provincial differences between malaria direct, indirect and total treatment costs in Madang and in Maprik. Such incremental costs were calculated through: (i) midpoint analysis, (ii) non-parametric bootstrap.

A midpoint analysis looked in a parametric way at whether mean values were statistically different across the two sites using t-tests. Firstly, to check for normality of distributions, Shapiro–Wilk tests were undertaken (Zhou *et al*. 1997a; Zhou *et al*. 1997b; Glick and Polsky 1999). Secondly, Levene tests were performed in order to check the hypothesis of equality of variances in the two different sample groups. As health care costs are typically positively skewed, the t-test based on the normality assumption could be inappropriate for evaluating the existence of statistically significant cost differences across sites. Therefore non-parametric bootstrap (Koopmanschap *et al*. 1995; Brouwer *et al*. 1997) was performed with the aim of estimating the standard error of the mean differences and to produce confidence intervals without making assumptions about the cost distribution. Non-parametric bootstraps were undertaken with 2000 bootstrap samples. The normality of the distribution of the mean of the bootstraps was tested through Shapiro–Wilk tests. When the distribution of the mean of the bootstraps was not normal, confidence intervals were calculated through BCa (Bias-corrected and accelerated) percentiles approximation (Efron and Tibshirani 1993).

Both approaches were used to estimate direct, indirect and total household costs, total household costs being the sum of direct and indirect costs. In the midpoint analysis, costs were broken down into their components. Time lost due to children's illness was also highlighted in the case of indirect costs.

The two different approaches used (midpoint analysis and non-parametric bootstrap) allowed the calculation of different values for the confidence intervals, leading to a better interpretation of household costs structures across sites.

To determine whether or not the null hypothesis is rejected, we set a critical significance level equal to 0.05. Stata 11 (Stata Corporation, College Station, TX, USA) was used for the midpoint analysis and R version 2.11.1 (The R Foundation for Statistical Computing) was used for bootstrapping.

Results

In total, 284 questionnaires were collected: 148 outpatients (72 in Maprik and 76 in Madang) and 136 inpatients (62 in Maprik and 74 in Madang). Table 1 shows the main characteristics of the sample split into outpatients and inpatients and

Table 1 Characteristics of the sample

	Inpatients		Outpatients	
	Maprik	Madang	Maprik	Madang
Child				
Sex				
Male	39 (63%)	36 (49%)	36 (50%)	42 (55%)
Female	23 (37%)	38 (51%)	36 (50%)	33 (44%)
Missing	0	0	0	1 (1%)
Average age	1 year, 4 months, (SD = 11 months)	1 year (SD = 10 months)	1 year, 5 months (SD = 10 months)	1 year, 7 months (SD = 10 months)
Carer				
Relationship to child				
Mother	52 (84%)	65 (88%)	62 (86%)	70 (92%)
Father	8 (13%)	6 (8%)	3 (4%)	4 (5%)
Other	2 (3%)	3 (4%)	6 (9%)	2 (3%)
Missing	0	0	1 (1%)	0
Type of work				
Gardening – subsistence farming	62 (100%)	46 (62%)	70 (98%)	75 (99%)
Housework (looking after your own home)	0	20 (27%)	0	0
Shop workers	0	4 (6%)	0	0
Other[a]	0	2 (3%)	1 (1%)	1 (1%)
Fishing	0	1 (1%)	0	0
Public servant	0	1 (1%)	1 (1%)	0
Average time lost (hours)	26.90 (SD = 19)	30.03 (SD = 18)	23.64 (SD = 22)	15.74 (SD = 11)

Notes: SD = standard deviation.

[a]In the inpatients case the 2 others were a second-hand seller and an administration officer; in the outpatient case there was a second-hand clothing seller in Maprik and a marketing worker in Madang.

divided by site. Males made up a higher proportion of inpatients in Maprik (63%), and of outpatients (55%) in Madang. Of the sample characteristics of patients in the two provinces, a higher mean age of 1 year and 7 months was recorded in Madang outpatients. The great majority of carers were mothers and most carers were subsistence farmers. The average time lost by carers of inpatients was 30 hours in Madang and 27 hours in Maprik. Carers of children treated in outpatient facilities reported losing approximately 24 hours in Maprik and about 16 hours in Maprik.

Direct and indirect household costs are discussed below from two perspectives. First, the impact of exploring uncertainty is discussed, and second, the composition of the costs are identified (and reported with reference to the bootstrap analysis, unless otherwise stated).

Uncertainty

Levene's test was used before mean comparisons through t-test to check for variance homogeneity. When Levene's test was significant, modified procedures that do not assume equality of variance were used. T-tests assessed the statistical significance of cost differences in direct and indirect outpatient costs and in direct and total inpatient costs (Table 2). To explore whether the confidence intervals of incremental costs might be affected by the normality assumption of distributions, Shapiro–Wilk tests were conducted. The null hypothesis of distribution normality of household expenditure was always rejected (Shapiro–Wilk tests $P < 0.001$). This result required us to adjust the estimated cost distributions through non-parametric bootstrapping. Cost distributions, as well as time lost, are described in Table 3.

Bootstrap distributions of the mean difference were not normal in the case of outpatient and inpatient indirect and total household costs. Therefore, BCa percentile was considered the best way to estimate confidence intervals in these cases.

Outpatient costs

While there was a difference between the mean total household costs for outpatient treatment of malaria in children from Madang in comparison with children treated at outpatient facilities in Maprik (US$ −1.67; 95% CI −4.16, 0.31), this was not statistically significant. Both direct and indirect costs differences were, however, statistically significant, with direct costs being higher in Madang (US$1.19; 95% CI 0.75, 1.65) and indirect costs being higher in Maprik (US$ −2.82; 95% CI −5.25, −1.14), respectively. Two main factors impacted on the statistically significant indirect and direct costs for outpatient facilities.

First, time lost accounted for most of the variability of indirect costs associated with outpatient visits. Difference in time lost was remarkably higher in Maprik than in Madang (hours −7.95; 95% CI −14.46, −3.00). This difference was predominantly related to non-salaried carers. Only two of the carers in the Maprik study site were salaried (Table 1), while in Madang only one carer utilizing an outpatient facility reported earning a wage.

Non-salaried carers in Maprik reported losing on average 24 hours, in comparison to non-salaried carers in Madang who reported losing just 16 hours in caring for their children who

Table 2 Outpatient and inpatient household costs estimates (US$ 2007)

	Mean difference Madang – Maprik	Lower limit 95%	Upper limit 95%
Outpatients			
Direct costs			
Midpoint analysis	1.19	0.73	1.66
User fees	0.53	0.43	0.62
Food	0.04	0.02	0.10
Transport	0.63	0.18	1.07
Bootstrap[a]	1.19	0.75	1.65
Bootstrap[c]	1.19	0.73	1.66
Indirect costs			
Midpoint analysis	−2.85	−4.92	−0.78
Bootstrap[b]	−2.82	−4.89	−0.87
Bootstrap[c]	−2.82	−5.25	−1.14
Time lost (hours)			
Midpoint analysis	−7.90	−13.58	−2.22
Bootstrap[b]	−7.95	−13.44	−2.25
Bootstrap[c]	−7.95	−14.46	−3.00
Total household costs[d]			
Midpoint analysis	−1.65	−3.86	0.55
Bootstrap[b]	−1.67	−3.82	0.54
Bootstrap[c]	−1.67	−4.16	0.31
Inpatients			
Direct costs			
Midpoint analysis	4.89	4.43	9.32
User fees	2.07	1.47	2.67
Food	1.41	0.29	2.53
Accomodation	1.28	0.89	1.66
Transport	0.14	−1.64	1.91
Bootstrap[a]	4.86	2.48	7.38
Bootstrap[c]	4.86	2.38	7.28
Indirect costs			
Midpoint analysis	6.23	−1.64	14.10
Bootstrap[b]	6.24	−1.39	13.81
Bootstrap[c]	6.24	1.54	19.64
Time lost (hours)			
Midpoint analysis	3.12	−3.17	9.41
Bootstrap[b]	3.30	−3.14	9.04
Bootstrap[c]	3.30	−3.72	8.58
Total household costs[d]			
Midpoint analysis	11.12	2.59	19.65
Bootstrap[b]	11.16	2.69	19.48
Bootstrap[c]	11.16	5.47	25.33

Notes: Bootstrap is based on 2000 bootstrap samples.
[a]Normally distributed (Shapiro–Wilk test: P value > 0.001.
[b]Not normally distributed (Shapiro–Wilk test: P value < 0.001).
[c]Bootstrap bias-corrected accelerated (BCa) interval method.
[d]Total household costs are given by: average direct costs across all respondents + average costs of income loss (taking into account true zeros) + the average costs of welfare loss (taking into account true zeros).

Table 3 Costs: summary statistics of malaria treatment costs

Site	Min	1st Quartile	Median	Mean	3rd Quartile	Max
Outpatients, Madang ($n = 76$); Maprik ($n = 72$)						
User fees (US$)						
Madang	0.00	0.00	0.58	0.70	0.78	1.94
Maprik	0.00	0.00	0.00	0.18	0.78	1.16
Food (US$)						
Madang	0.00	0.00	0.00	0.05	0.00	1.94
Maprik	0.00	0.00	0.00	0.01	0.00	0.78
Accomodation (US$)						
Madang	0.00	0.00	0.00	0.00	0.00	0.00
Maprik	0.00	0.00	0.00	0.00	0.00	0.00
Transportation (US$)						
Madang	0.00	0.00	0.21	1.06	1.08	6.48
Maprik	0.00	0.00	0.00	0.43	0.19	4.66
Total direct costs (user fees + food + accommodation + transportation) (US$)						
Madang	0.00	0.78	1.03	1.81	1.79	7.26
Maprik	0.00	0.00	0.08	0.62	0.78	4.66
Time lost (hours)						
Madang	2.00	8.00	12.00	15.74	19.00	58.00
Maprik	2.00	10.00	18.00	23.64	33.00	140.00
Indirect costs (US$)						
Madang	0.73	2.91	4.37	5.73	6.92	21.12
Maprik	0.00	3.64	6.55	8.58	12.01	50.97
Total household costs (total direct costs + indirect costs) (US$)						
Madang	2.04	4.85	6.07	7.54	9.51	24.61
Maprik	0.00	4.39	6.88	9.20	12.40	52.91
Inpatients, Madang ($n = 74$); Maprik ($n = 62$)						
User fees (US$)						
Madang	0.00	0.00	1.07	2.27	4.47	6.99
Maprik	0.00	0.00	0.00	0.20	0.00	7.77
Food (US$)						
Madang	0.00	0.78	1.69	2.76	3.88	19.42
Maprik	0.00	0.00	0.17	13.49	1.16	19.42
Accomodation (US$)						
Madang	0.00	0.28	0.85	1.31	1.94	7.77
Maprik	0.00	0.00	0.00	0.03	0.00	1.01
Transportation (US$)						
Madang	0.00	0.39	1.28	2.98	3.01	27.96
Maprik	0.00	0.00	0.43	2.85	3.11	34.95
Total direct costs (user fees + food + accommodation + transportation) (US$)						
Madang	0.00	4.08	7.61	9.32	11.84	40.19
Maprik	0.00	0.62	2.14	4.30	6.06	42.72
Time lost (hours)						
Madang	5.00	16.00	26.5	30.03	36.00	84.00
Maprik	6.00	16.00	22.00	26.90	32.00	126.00
Indirect costs (US$)						
Madang	1.63	5.82	9.65	15.88	14.56	279.60
Maprik	0.00	5.82	7.64	9.65	11.65	45.87
Total household costs (total direct costs + indirect costs) (US$)						
Madang	4.05	10.97	18.48	25.20	26.07	291.70
Maprik	2.18	8.28	11.16	14.08	16.99	59.85

were treated at an outpatient facility. The maximum number of lost hours reported by non-salaried carers was also higher in Maprik (140 hours) than the maximum number of hours reported by non-salaried carers in Madang (58 hours).

Second, charges imposed by facilities and distance to facilities contributed to the differences in direct outpatient costs. The breakdown of direct outpatient costs highlighted significantly higher consultation fees in Madang than in Maprik, with a difference, according to the midpoint analysis, of US$0.53 (95% CI 0.43, 0.62) for user fees and US$0.63 (95% CI 0.18, 1.07) for transportation costs.

Inpatient costs

In contrast to outpatient costs, the difference between the inpatient total household costs in Madang compared with those in Maprik (US$11.16; 95% CI 5.47, 25.33) was statistically significant. Both direct and indirect household costs for inpatient malaria treatment in children were significantly higher in Madang than in Maprik, with a difference of US$4.86 (95% CI 2.48, 7.38) and of US$6.24 (95% CI 1.54, 19.64), respectively.

The significantly higher inpatient direct costs in Madang are associated with positive incremental health service charges (US$2.07; 95% CI 1.47, 2.67), the incremental costs associated with obtaining food (US$1.41; 95% CI 0.29, 2.53) and accommodation for the carer while staying with the patient (US$1.28; 95% CI 0.89, 1.66). Incremental transportation costs were not statistically significant (US$0.14; 95% CI −1.64, 1.91).

While inpatient indirect costs were significantly higher in Madang compared with Maprik, the difference in time lost was not statistically significant (hours 3.30; 95% CI −3.72, 8.58). Carers in Madang lost slightly more time (30 hours) on average than people in Maprik (27 hours). Eight carers reported an actual salary loss (income loss) as opposed to a shadow price imputed from ILO labour rates (welfare loss) and all of them were in Madang. The reported loss of salary was always greater than the minimum wage applied to non-salaried carers' time when calculating welfare loss.

Confidence intervals

The real benefit of having undertaken two approaches, midpoint analysis and non-parametric bootstrap, is in the estimation of confidence intervals. Confidence intervals reflect the uncertainty of the location of the true population mean, when a sample of such a population is analysed.

The width of confidence intervals changed between midpoint and non-parametric bootstrap. The main changes in confidence intervals referred to inpatients total household costs (changing from US$11.12; 95% CI 2.59, 19.65 to US$11.16; 95% CI 5.47, 25.33), inpatients direct costs (changing from US$4.89; 95% CI 4.43, 9.32 to US$4.86; 95% CI 2.48, 7.38) and indirect costs (changing from US$6.23; 95% CI −1.64, 14.10 to US$6.24; 95% CI 1.54, 19.64). In this last case, incremental costs were not statistically significant when estimated through midpoint analysis, while these were statistically significant when estimated through non-parametric bootstrap.

Mean values of costs can be considered as informative to policy makers in their decision process and such values remain largely the same between the midpoint analysis and the non-parametric bootstrap (Thompson and Barber 2000). However, in the event that health policy decisions were based on indirect cost differences between the two areas, midpoint analysis would fail to give accurate information. More precisely, midpoint analysis suggests a statistically insignificant difference in indirect inpatient cost, whereas bootstrapping shows statistically significant differences in costs across the two provinces. It is important that policy makers are aware that a pronounced difference exists across the two provinces, which is not down to chance given the high level of costs borne by households when treating inpatient malaria.

Discussion

The most important finding that arose from this analysis was the degree of disparity between the two sites. This contrast was apparent in both the direct and indirect costs associated with seeking either outpatient or inpatient malaria treatment.

Differences in direct costs were associated with variations between health system user fees across the geographic areas. There is no flat fee structure across PNG, with different health facilities charging different amounts. In particular, health facilities in Madang were found to charge more than health facilities in Maprik. This is an important finding for the uptake of health interventions.

The primary differences in indirect costs were associated with the reduction in carers' paid and unpaid productivity, referred to in this paper as income loss and welfare loss, respectively. There is continued debate about which micro-economic tools best reflect these costs (Becker 1965; Koopmanschap *et al*. 1995; Brouwer *et al*. 1997; Weinstein *et al*. 1997). In a recent paper estimating the economic burden of malaria on households in Vietnam, two approaches were summarized for assessing indirect costs (Morel *et al*. 2008). Output-based approaches value the product forgone by identifying the loss of time associated with an illness episode and attaching zero value to unpaid housework (primarily due to the difficulty of making accurate estimates of its output) (Goldschmidt 1982). Alternatively, opportunity cost approaches use average wages paid to local workers as proxies for the value of work of unpaid workers (Liljas 1998). In our analysis the later method was used. The main occupations in the study area were subsistence farming or domestic activities; to assume no costs were associated with these activities would underestimate the economic impact of childhood malaria on households. Therefore, formally-paid wages were used as proxies for unpaid work. All indirect costs were considered to contribute to income whether the products (or activities) were eventually sold or consumed within the household, as has been done elsewhere (Morel *et al*. 2008). We follow Schnittgrund's argument (Schnittgrund 1980) that time spent on non-market activities which still have a utility value to the individual and their household should not be classified as non-productive simply because such productivity is not included in gross domestic product (GDP). Therefore time spent on home production (in our case, caring for a sick child) as well as production associated with market goods and services have both been recognized.

Statistically significant differences were noted in indirect outpatient costs and time lost across the two sites. Maprik had higher mean values than Madang, suggesting that either (i) real differences exist, or (ii) people evaluate time lost from work differently. Individual perceptions around what constitutes work may depend on cultural and socio-economic factors. Many of the prevalent economic theories of growth are based on the general equilibrium theory, which assumes that economic agents choose to split their time between work and leisure according to their preferences and other factors, such as sex, age and social status (Haworth and Veal 2004). From this individual choice, passing through a complex aggregation process, a general economic equilibrium is generated (Mas-Colell 1990). This study demonstrates that a certain level of division of labour and a certain degree of structure of the economic system are needed for economic agents to be able to actually separate these two concepts and, thus, identify a difference between work and leisure time (Rao and Cooray 2009). The general equilibrium theory may better explain economic growth in Madang where the economy is more structured and the division of labour more marked as the local economy was more diversified, and less of an agro-economy.

Due to the important differences in both direct and indirect costs found across the two sites, it is recommended that local data instead of national data should be used when undertaking health planning activities. The only regional-specific data in PNG that the authors identified were reported by the Human Poverty Index (HPI) and the Human Development Index (HDI) (Asian Development Bank 2000). According to the HPI, the East Sepik province (which encompasses Maprik) and the Madang province have a similar rank, with Madang considered to be less poor than East Sepik (HPI respectively of 42.3 and 47.3). Yet, according to the HDI the two provinces are different, with Madang having a higher value of HDI than Maprik (HDI respectively of 0.336 and 0.304). Since HDI is a synthesis of GDP, life expectancy, literacy and educational attainment, it appears that people in Madang might be better able to accommodate the higher costs of treatment than people in Maprik.

There is reason to believe that the intra-country household cost differences highlighted in this study could be present in other settings (Drummond and Pang 2001). These findings are particularly relevant for cost-effectiveness analysis of health interventions undertaken on a national scale. Household savings from fewer cases of malaria derived from the same intervention at national level may have a varying degree of impact on families' budgets at a more disaggregated level.

The heterogeneity of household expenditure should be taken into account when the equity of treatment is debated.

Treatment disparities have been found in many studies investigating access to and use of malaria treatment, with uptake of health care services concentrated among the least poor (Schellenberg *et al*. 2003; Worrall *et al*. 2005; Matovu *et al*. 2009). Strategies for targeting the poor must be underpinned by accurate information about the nature and the causes of inequalities in utilization (Matovu *et al*. 2009) which, in part, are driven by the economic burden childhood malaria places on a household. If equity is among the aims of policy makers, it is important to know which variables determine differences in access to health care between areas, groups or populations considered.

This study also presented an important methodological component by validating the benefit of using non-parametric bootstrap techniques for confidence interval calculations. Confidence intervals can consistently vary when calculated through parametric methods or when calculated through non-parametric bootstrap, as in the case of direct inpatient costs. While it is clear that mean values are an essential measure, uncertainty also needs to be represented as accurately as possible in order to guide important policy decisions.

This study had certain limitations. For example, the costs of inpatient care may have been under-reported because in order to ensure that the malaria episode was recorded, carers were interviewed prior to discharge from the facility, and therefore any costs that may have been incurred post-interview were not necessarily captured.

A mixed methods approach using both quantitative and qualitative research would have provided more insight into the socio-economic and cultural interpretations of the financial value of time use. While quantitative analysis measured differences in the reported amount of working time and its financial value, a deeper understanding of what individuals perceived to be associated with lost time would have explained the findings in greater depth.

Conclusions

While it is recognized that both direct and indirect costs associated with seeking malaria treatment significantly impact on a household budget, extrapolating the economic impact in one region of a country to the national level may not always provide a realistic assessment. This study suggests that any economic analysis of household costs for malaria treatment should consider the potential for intra-country variance. Intra-country differences also need to be understood by policy makers in order to build national health interventions flexible enough to adapt to local contexts. In order to reach such a level of accuracy of information, researchers should combine appropriate statistical methods to highlight cost variation and uncertainty.

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Conflict of interest

None declared.

Endnote

[1] The central limit theorem states conditions under which the mean of a sufficiently large number of independent random variables, each with finite mean and variance, will be approximately normally distributed (Rice 1995).

References

Altman DG, Gore SM, Gardner MJ, Pocock SJ. 1983. Statistical guidelines for contributors to medical journals. *British Medical Journal (Clinical Research Ed.)* **286**: 1489–93.

Asenso-Okyere WK, Dzator JA. 1997. Household cost of seeking malaria care. A retrospective study of two districts in Ghana. *Social Science & Medicine* **45**: 659–67.

Asian Development Bank. 2000. Papua New Guinea: country economic review. Manila: Asian Development Bank.

Briggs A, Gray A. 1998. The distribution of health care costs and their statistical analysis for economic evaluation. *Journal of Health Services Research and Policy* **3**: 233–45.

Brooker S, Kabatereine NB, Fleming F, Devlin N. 2008. Cost and cost-effectiveness of nationwide school-based helminth control in Uganda: intra-country variation and effects of scaling-up. *Health Policy and Planning* **23**: 24–35.

Brouwer WB, Koopmanschap MA, Rutten FF. 1997. Productivity costs in cost-effectiveness analysis: numerator or denominator: a further discussion. *Health Economics* **6**: 511–4.

Cattani JA, Tulloch JL, Vrbova H *et al.* 1986. The epidemiology of malaria in a population surrounding Madang, Papua New Guinea. *American Journal of Tropical Medicine and Hygiene* **35**: 3–15.

Davy C, Sicuri E, Ome M *et al.* 2010. Seeking treatment for symptomatic malaria in Papua New Guinea. *Malaria Journal* **9**: 268.

Deressa W, Hailemariam D, Ali A. 2007. Economic costs of epidemic malaria to households in rural Ethiopia. *Tropical Medicine & International Health* **12**: 1148–56.

Drummond MF, Pang F. 2001. Transferability of economic evaluation results. In: Drummond MF, McGuire A (eds). *Economic Evaluation in Health Care: Merging Theory with Practice*. New York: Oxford University Press, pp. 256–76.

Efron B, Tibshirani R. 1993. *An Introduction to the Bootstrap*. New York and London: Chapman and Hall.

Genton B, Al-Yaman F, Beck HP *et al.* 1995. The epidemiology of malaria in the Wosera area, East Sepik Province, Papua New Guinea, in preparation of vaccine trials. II. Mortality and morbidity. *Annals of Tropical Medicine and Parasitology* **89**: 377–90.

Glick HA, Polsky D. 1999. Analytic approaches for the evaluation of costs. *Hepatology* **29**(6 Suppl.):18S–22S.

Glied S. 1996. Estimating the indirect cost of illness: an assessment of the forgone earnings approach. *American Journal of Public Health* **86**: 1723–8.

Goeree R, Burke N, O'Reilly D *et al.* 2007. Transferability of economic evaluations: approaches and factors to consider when using results from one geographic area for another. *Current Medical Research & Opinion* **23**: 671–82.

Goldschmidt C. 1982. Economic evaluation of unpaid household work: a review of economic evaluation methods. *Women, Work & Development, no. 148*. Geneva: International Labour Office.

Hauck V, Mandie-Filer A, Bolger J. 2005. Ringing the church bell: the role of churches in governance and public performances in Papua New Guinea. *ECDPM Discussion Paper no. 57E*. Maastricht: European Centre for Development Policy Management.

Haworth JT, Veal AJ (eds). 2004. *Work and Leisure*. London: Routledge.

ICH Expert Working Group. 1996. ICH Harmonised Tripartite Guideline: guideline for good clinical practice, E6(R1). Geneva: ICH.

ILO (undated). ILO Suva. Online at: http://www.ilo.org/public/english/region/asro/suva/infocenter.htm.

Konradsen F, van der Hoek W, Amerasinghe PH, Amerasinghe FP. 1997. Measuring the economic cost of malaria to households in Sri Lanka. *American Journal of Tropical Medicine and Hygiene* **56**: 656–60.

Koopmanschap MA, Rutten FF, van Ineveld BM, van Roijen L. 1995. The friction cost method for measuring indirect costs of disease. *Journal of Health Economics* **14**: 171–89.

Lagarde M, Palmer N. 2008. The impact of user fees on health service utilization in low- and middle-income countries: how strong is the evidence? *Bulletin of the World Health Organization* **86**: 839–48.

Liljas B. 1998. How to calculate indirect costs in economic evaluations. *Pharmacoeconomics* **13**: 1–7.

Mas-Colell A. 1990. *The Theory of General Economic Equilibrium*. Cambridge: Cambridge University Press.

Matovu F, Goodman C, Wiseman V, Mwengee W. 2009. How equitable is bed net ownership and utilisation in Tanzania? A practical application of the principles of horizontal and vertical equity. *Malaria Journal* **8**: 109.

Morel CM, Thang ND, Xa NX *et al.* 2008. The economic burden of malaria on the household in south-central Vietnam. *Malaria Journal* **7**: 166.

Muller I, Smith T, Mellor S *et al.* 1998. The effect of distance from home on attendance at a small rural health centre in Papua New Guinea. *International Journal of Epidemiology* **27**: 878–84.

Muller I, Bockarie M, Alpers M, Smith T. 2003. The epidemiology of malaria in Papua New Guinea. *Trends in Parasitology* **19**: 253–9.

OANDA. 2007. Historic Currency Converter. Online at: http://www.oanda.com/convert/fxhistory.

Olsen JA, Richardson J. 1999. Production gains from health care: what should be included in cost-effectiveness analyses? *Social Science & Medicine* **49**: 17–26.

Onwujekwe O, Chima R, Okonkwo P. 2000. Economic burden of malaria illness on households versus that of all other illness episodes: a study in five malaria holo-endemic Nigerian communities. *Health Policy* **54**: 143–59.

Rao BB, Cooray A. 2009. How useful is Growth Literature for Policies in the Developing Countries? Munich Personal RePEc Archive Paper No. 14573. Online at: http://ideas.repec.org/p/pra/mprapa/14573.html.

Rice JA. 1995. *Mathematical Statistics and Data Analysis*. Belmont, CA: Duxbury Press.

Rutten-van Molken MP, van Doorslaer EK, van Vliet RC. 1994. Statistical analysis of cost outcomes in a randomized controlled clinical trial. *Health Economics* **3**: 333–45.

Schellenberg JA, Victoria CG, Mushi A *et al.* 2003. Inequities among the very poor: health care for children in rural southern Tanzania. *The Lancet* **361**: 561–6.

Schnittgrund KP. 1980. Productive time of household heads. *Journal of Consumer Studies and Home Economics* **4**: 239–48.

SIL International. 2005. *Ethnologue: languages of the world*. Dallas, TX: SIL International.

Su TT, Sanon M, Flessa S. 2007. Assessment of indirect cost-of-illness in a subsistence farming society by using different valuation methods. *Health Policy* **83**: 353–62.

Tan-Torres T, Baltussen R, Adam T *et al.* 2003. *Making Choices in Health: WHO Guide to Cost-Effectiveness Analysis*. Geneva: World Health Organization.

Thompson SG, Barber JA. 2000. How should cost data in pragmatic randomised trials be analysed? *British Medical Journal* **320**: 1197–200.

US Department of State. 2010. Background note: Papua New Guinea. Online at: http://www.state.gov/r/pa/ei/bgn/2797.htm, accessed 11 October 2010.

WHO Western Pacific Region. 2004. Papua New Guinea: Health situation. Online at: http://www.wpro.who.int/countries/2004/png/health_situation.htm.

World Health Organization. 2008. World Malaria Report 2008. Geneva: World Health Organization. Online at: http://www.who.int/malaria/wmr2008/.

World Health Organization. 2009. World Malaria Report 2009. Geneva: World Health Organization. Online at: http://www.who.int/malaria/world_malaria_report_2009/en/index.html.

Worrall E, Basu S, Hanson K. 2005. Is malaria a disease of poverty? A review of the literature. *Tropical Medicine & International Health* **10**: 1047–59.

Xu K, Evans DB, Kawabata K *et al.* 2003. Household catastrophic health expenditure: a multicountry analysis. *The Lancet* **362**: 111–7.

Zhou XH, Gao S, Hui SL. 1997a. Methods for comparing the means of two independent log-normal samples. *Biometrics* **53**: 1129–35.

Zhou XH, Melfi CA, Hui SL. 1997b. Methods for comparison of cost data. *Annals of Internal Medicine* **127**: 752–6.