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Cost and cost-effectiveness of nationwide school-based helminth control in Uganda:

intra-country variation and effects of scaling-up

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Abstract

Estimates of cost and cost-effectiveness are typically based on a limited number of small-scale studies with no investigation of the existence of economies to scale or intra-country variation in cost and cost-effectiveness. This information gap hinders the efficient allocation of health care resources and the ability to generalize estimates to other settings. The current study investigates the intra-country variation in the cost and cost-effectiveness of nationwide school-based treatment of helminth (worm) infection in Uganda. Programme cost data were collected through semi-structured interviews with districts officials and from accounting records in six of the 23 intervention districts. Both financial and economic costs were assessed. Costs were estimated on the basis of cost in US$ per schoolchild treated and an incremental cost effectiveness ratio (cost in US$ per case of anaemia averted) was used to evaluate programme cost-effectiveness. Sensitivity analysis was performed to assess the effect of discount rate and drug price. The overall economic cost per child treated in the six districts was US$ 0.54 and the cost-effectiveness was US$ 3.19 per case of anaemia averted. Analysis indicated that estimates of both cost and cost-effectiveness differ markedly with the total number of children which received treatment, indicating economies of scale. There was also substantial variation between districts in the cost per individual treated (US$ 0.41-0.91) and cost per anaemia case averted (US$ 1.70-9.51). Independent variables were shown to be statistically associated with both sets of estimates. This study highlights the potential bias in transferring data across settings without understanding the nature of observed variations.

Keywords

cost analysis; cost-effectiveness; economic evaluation; variation; scaling up; helminth control; Uganda

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Authorship

Simon Brooker conceived and designed the study, collected cost data and undertook cost-effectiveness analysis and wrote the first draft of the paper. Narcis Kabatereine coordinated the national control programmes, collected cost data and contributed to the final draft. Fiona Fleming assisted in cost data collection and contributed to the final draft. Nancy Devlin contributed towards the study design and contributed to the analysis and interpretation of the data and to the final draft.

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Introduction

Cost-effectiveness analysis has become a principal tool to evaluate health interventions, guiding health policy in both developed (McDaid et al., 2003) and developing countries (World Bank, 1993; Jamison et al. 2006). Estimates of cost-effectiveness are typically taken from a single study or a few small-scale studies in different countries (Walker and Fox-Rushby, 2000), with no attempt to review the possible variation in estimates. However, because both intervention costs and effectiveness differ among locations, a single estimate of cost-effectiveness is unlikely to be universally applicable (Musgrove and Fox-Rushby, 2006). More probable is that costs and cost-effectiveness will vary, even within a single country. For instance, intra-country variation in costs have been demonstrated in the delivery of routine immunization in Peru (Walker et al., 2004), antenatal care in Cuba and Thailand (Hutton et al., 2004), a bednet distribution programme in Malawi (Stevens et al., 2005) and a lymphatic filariasis elimination programme in Egypt (Ramzy et al. 2005). Variations in average costs may arise in the short run from differences in the relative costs of inputs; differences in technical efficiency; or, in the long run, from factors associated with economies of scale (Folland et al., 2004). Differences may also reflect variation in respect to the demography and epidemiology of disease, availability of health care resources and system of health delivery (Drummond and Pang, 2001). Understanding how and why costs vary can help assess the degree to which cost and cost-effectiveness estimates can be reliably extrapolated across different settings and also enable health planners and policy makers discern what drives costs and plan future budgets (O'Brien, 1997; Bryan and Brown 1998; Spath et al., 1999; Drummond et al. 1992; Drummond and Pang, 2001; Walker et al. 2004). This understanding is particularly important for global health programmes which implement a common health package in a range of settings. For example, a number of initiatives are now underway which seek to control disease due to a number of tropical diseases, including those caused by parasitic helminth (worm) infections (Albonico et al., 2006; Boatin and Richards, 2006; Ottesen, 2006; Fenwick et al., 2006).

The staff of these initiatives, together with national programme staff, also need information on how costs change as the programmes are gradually scaled-up. In economics, changes in the level of output may change average costs; as output increases, average costs either remain constant (constant returns to scale), decrease (economies of scale) or increase (diseconomies of scale) (Folland et al., 2004). Many studies assume constant returns to scale and take average costs per recipient and multiply them by projected output levels (e.g. Fenwick et al., 2005; Brady et al., 2006). In practice however available studies demonstrate that average costs vary at different levels of output (Over, 1998; Valdmanis et al., 2003; Mansley et al., 2002; Elbasha and Messonnier, 2004).

There is a clear need for empirical evidence to better understand variations in cost and cost-effectiveness, particularly in the context of large-scale control programmes. This paper assesses both variation in costs and cost-effectiveness, and the effect of scaling-up on costs of a nationwide helminth control programme. The specific aims are to (1) investigate the intra-country variation in the cost and cost-effectiveness of a national school-based schistosomiasis and soil-transmitted helminth (STH) control programme in Uganda, (2) determine the effects of scaling up on costs and cost-effectiveness, and (3) identify the main determinants of average costs.

Description of the control programme

In 2003, the Ugandan Ministry of Health (MoH) launched its national schistosomiasis and STH control programme (Kabatereine et al., 2006a,b). Implemented vertically through the Vector Control Division (VCD) in Kampala, the programme is and aims to provide

anthelmintic (deworming) treatment to schools and communities at risk of morbidity due to helminth infection. In brief, the programme comprises the following activities: community sensitization, training of teachers and community drug distributors (CDDs) and school-based delivery of two anthelmintic drugs. Mass treatment with praziquantel to treat schisotosomiasis and with albendazole to treat soil-transmitted helminths was given to all schools and communities in targeted areas. Treatment in schools is carried out by teachers and in communities by CDDs. The programme manager and VCD headquarters staff have overall responsibility for the programme and regularly visit districts to monitor progress. Implementation of the programme at the district level is undertaken by District Vector Control Officers (DVCOs) and district health teams.

To help create awareness and political engagement, a series of national workshops were held in Kampala between 2001 and 2005 (two in 2001, two in 2002 and one each in 2004 and in 2005). The implementation of control began with a pilot phase from April to October 2003 targeting 400,00 people, with one subcounty selected for mass treatment in each of the 18 most affected districts (Kabatereine et al., 2006a). In 2004, the number of sub-counties targeted in each of the 18 districts was increased and in 2005, the programme was expanded to include 23 districts, targeting 2.3 million people (Kabatereine et al., 2006b). In each district, training workshops provided teachers and CDDs with a basic understanding of schistosomiasis and STH and how to complete record forms and to administer tablets. The design of training and number of participants varying between districts. Health education messages were delivered through posters, booklets and audio and film media. All information, education and communication (IEC) material was translated into various local languages. Imported drugs were cleared at Entebbe airport by the Uganda National Medical Stores, who transported them to VCD headquarters. Drugs and IEC material were either transported to the districts by VCD or collected by the districts during routine visits to Kampala. Drug registration and treatment included compiling school enrolment data and community census information to determine the target population and drug needs. The number of tablets provided to each school was calculated on the basis of treatment registers completed by head teachers and CCDs. The drugs were delivered to each school by the DVCOs and were received by the head teacher. Tablets were then administered by teachers on a specified day in all schools under the supervision of the head teachers and community health workers. In communities, treatment was provided by CCDs. Praziquantel (25mg/kg) was administered to individuals on the basis of height, using locally made height poles, and every individual was given a single dose of albendazole (400mg). All unused tablets were recovered by DVCOs who also compiled a report of activities.

Data and methods

Only costs associated with school-based treatment are considered here because of the global focus of helminth control on the school age child (Bundy et al., 2006) and the availability of detailed effectiveness data for schoolchildren (Kabatereine et al., 2007).

Cost analysis

Cost data were collected retrospectively from the VCD team in Kampala and from six of the 23 intervention districts (Figure 1). Districts were chosen to reflect differences in disease transmission (Kabatereine et al., 2004) and in socio-economic and health service infrastructure. Data collection was carried out between February and June 2006. A semi-structured questionnaire was drafted and was revised and amended during joint discussions with MoH officials. Data were collected by interviews with district officials using the final questionnaire and by consultation of the programme accounting system in Kampala. Documentation related to expenditure had been checked by each district accountant for accountability and cross-checked by the research team for accuracy.

The perspective adopted in the evaluation was the government, rather than society since the costs of accessing treatment are negligible, as children were treated in their own schools. Both financial and economic costs were estimated. Financial costs represent cash expenditure paid for the implementation of the intervention on an annual basis. Economic costs included the opportunity cost of using existing Ministry of Health staff and school teachers as well as annuitized capital costs, and represent the true cost of any intervention. Opportunity costs for staff were calculated from salary costs, based on Ugandan civil service pay scales for 2005. Capital costs were annuitized over the useful life of each item using a discount rate of 3%, consistent with the recommendations of the World Bank (1993). Such annuitization enables an equivalent annual cost to be estimated and reflects the value-in-use of capital items, rather than reflecting when the item was purchased. The assumed useful life of buildings was 30 years, vehicles 7.5 years, motorcycles 4 years and computers 3 years. Vehicle running costs also included maintenance and insurance. The purchase, freight and insurance of drugs was paid in foreign currency (US$). All other costs were paid in Uganda Shillings (USh) and converted to US dollars using official exchange rates, based average yearly exchange rate: 2003, 1777 USh = 1 UD$; 2004, 1807 USh; and 2005, 1844 USh (www.oanda.com/convert/classic). Monetary costs were adjusted for inflation over time using the Gross Domestic Product (GDP) implicit price deflator (http://ifs.apdi.net/imf/logon.aspx) and expressed in 2000 prices. Details on the resources employed, their unit costs and quantities consumed are provided in the appendix. All costs directly related to research activities were excluded.

The cost data are organized in six main cost centres: (i) programme running costs; (ii) community awareness; (iii) training; (iv) imported drugs; (v) drug registration and distribution; and (vi) IEC material. The different cost components of intervention were identified using an ingredients approach, considering both the number of units and the prices of units in local currency (Ugandan Shillings). The unit cost data were combined with numbers treated to calculate, on a district-by-district basis, the average cost per child treated. The relationship between the cost per child treated and the percentage of overall costs due to different cost centres and other independent demographic and geographic variables was assessed using a non-parametric Spearman rank correlation.

Effectiveness

Evidence of the programme effectiveness was measured in terms of anaemia cases averted. Epidemiological data were collected prospectively through longitudinal surveys conducted in 30 schools between 2003 and 2005. The details of the sampling strategy, survey design and procedures are provided elsewhere (Brooker et al., 2004; Kabatereine et al., 2007). Population-based measures of programme impact included parasitological and haematological data which were collected from randomly selected schoolchildren who were followed up over three years. Anaemia is defined as haemoglobin concentration (Hb) <110 g/L. The current analysis focuses on those districts where cost data were collected, thereby excluding effectiveness data from Arua, Bugiri and Mayunde districts. The number of cases of anaemia averted was calculated by multiplying the absolute difference in proportion of anaemia cases averted between 2003 and 2005 by the total number of children treated. This was calculated on a district-by-district basis, as well as, overall, assuming the mean difference in proportion of anaemia cases averted among districts.

Cost-effectiveness analysis

The counterfactual is defined as ‘do-nothing’. This is justified on the basis that prior to the current control programme, no efforts were made to control helminth infection in the country, with only passive detection of cases in health centres and presumptive treatment, although in practice, anthelmintic drugs were rarely available. Cost-effectiveness is defined

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in terms of the cost per case of anaemia averted, and cost-effectiveness ratios are based on annual economic costs.

Sensitivity analysis

Sensitivity analysis allows for uncertainty within the economic evaluation. It shows how responsive the result is to changes in key economic parameters but also gives an indication of the robustness of the estimate to changes in unknown variables. Sensitivity analysis was undertaken to investigate the effect on the results of varying the discount rate (reduced to 1% and increased to 10%), the prices of the drugs (reduced by 10% and 20% to reflect the use of cheaper drugs in the future) and effectiveness of treatment in reducing the proportion of anaemia case (reduced by 33% and 50% to reflect differences in the impact of treatment on anaemia in different transmission settings). One-way scenario sensitivity analysis was carried out to assess the impact of key variables on estimates of the cost per anaemia case averted.

Results

Total financial and economic costs

The total financial cost of the intervention in the six districts was estimated at US$ 161,312. The financial costs per district ranged from US$ 18,015 in Masindi district to US$ 33,809 in Hoima district. The economic cost of the intervention was calculated by valuing staff time and annuitizing capital costs to provide an equivalent annual cost. The economic costs of the intervention in each district are summarized by the major cost centres in Table 1. The total economic cost was estimated at US$ 218,303: ranging from US$ 25,624 in Masindi district to US$ 44,958 in Hoima district). In each district, the largest individual cost item was the purchase of drugs, ranging from 23.1% of total costs in Masindi district in 2003 to 52.1% in Moyo district in 2005. Community sensitization activities and IEC materials were the next largest items (Table 1).

Costs per children treated

The overall financial cost per child treated in the six districts was US$ 0.39. The total economic cost per child treated in the six districts was US$ 0.54, which includes the imputed value of labour as well as annuitized capital costs. Considerable variation in the economic costs per child treated existed between districts and between years, ranging from US$ 0.41 to US$ 0.91 (Table 2). The economic delivery cost per child treated (which excludes drug cost) also varied considerably: US$ 0.19-0.69. The cost per child treated is highly sensitive to the total number of children treated (Figure 2). Increasing the number of children treated can significantly decrease the cost per child treated (Figure 2a; Spearman's rho: -0.93, $p<0.001$), suggestive of economies of scale. Similar economies of scale were observed in the delivery cost per child treated (Figure 2b; Spearman's rho: -0.93, $p<0.001$).

In order to investigate possible causes of observed variation in costs, the relationship between delivery cost per child treated and the percentage of overall costs due to different cost centres was investigated. Cost per child treated was significantly associated with the percentage of overall costs due to sensitization and awareness (Spearman's rho: 0.769, $p=0.0002$). The majority of the costs involved here are per diems (allowances) rates paid to district officials, which ranged from US$ 4.95-15.44, although the correlation between allowance rates and cost per child treated was non-significant (Spearman's rho: 0.19, $p=0.444$). Differences in demographic and geographic factors, including distance of each district from Kampala, geographical area and population density of the district, and in epidemiological factors, such as baseline intensity of infection and reduction in infection following treatment, were not significantly associated with costs per child treated.

Cost-effectiveness

Among the 1,455 children monitored for the three-year period, the percentage of anaemic children, defined as Hb<110 g/L, fell from 35.2% in 2003 to 18.5% in 2005, following three rounds of treatment. This translates to a 52.5% reduction in the proportion of anaemia cases within the study population. Table 3 reports the proportion of anaemia cases averted over the three year period by district. Overall, 0.4 million children were treated at an estimated cost of US$ 3.19 per case of anaemia averted. Cost-effectiveness ranged from US$ 1.70 in Moyo district to US$ 9.51 in Masindi district. Cost-effectiveness decreased with increasing cost per child treated (Figure 3a; Spearman's rho: 0.940.19, p=0.005) and increased with increasing difference in the proportion of anaemia as a result of the intervention (Figure 3b; Spearman's rho: 1.0, p<0.0001). This suggests that neither costs nor effectiveness are constant and therefore cost-effectiveness varies between districts. Figure 3c indicates a negative association between cost-effectiveness and the number of children receiving treatment (Spearman's rho: -0.828, p=0.04), suggesting that there are increasing returns to scale in cost-effectiveness with respect to the target population.

Sensitivity analysis

The sensitivity of cost-effectiveness (cost per anaemia case averted) to variation in key parameters was explored (Table 4). Varying the discount rate made little difference to the estimate of cost-effectiveness. Reducing the prices of drugs by 10% and 20% reduced the cost per anaemia cost averted to US$ 3.07 and US$ 2.94, respectively.

Discussion

The cost of school-based control of helminth infection has been widely documented in a number of pilot programmes (Holland et al., 1996; Guyatt et al., 1993, 1994; Guyatt, 2003; Partnership for Child Development, 1998, 1999; Mascie-Taylor et al., 1999). Few studies, however, have looked at costs of school-based control under nationwide programmatic conditions (Sinuon et al., 2005; Gabrielli et al., 2006). This current study is the first to document both the costs and cost-effectiveness of a national school-based control programme involving mass treatment for schistosomiasis using praziquantel and for intestinal nematodes using albendazole. The overall economic cost per child treated in the six districts was US$ 0.54, the overall financial cost per child treated was US$ 0.39, and the cost-effectiveness was US$ 3.19 per case of anaemia averted.

These estimates fall below the range of estimates from the experience of the Partnership for Child Development in Africa, where the financial cost per child treated with praziquantel and albendazole was estimated to be US$ 1.22 and US$ 0.24, respectively in Ghana and US $ 0.79 and US$ 0.23, respectively in Tanzania (Partnership for Child Development, 1998, 1999). The related economic costs were US$ 2.94 and US$ 0.27 in Ghana and US$ 1.32 and US$ 0.26 in Tanzania. The programmes in Ghana and Tanzania included prior screening of urinary schistosomiasis at the school level using a questionnaire about symptoms of urinary schistosomiasis, administered by teachers, adding to overall costs. Such an approach is not applicable for intestinal schistosomiasis - the species endemic throughout in Uganda - because of the non-specific nature of its symptoms, and therefore mass treatment was provided to all schools in target subcounties. Furthermore, both the praziquantel and albendazole used in the Ghana and Tanzania programmes were proprietary and not generic products and therefore costed more than in the Uganda programme, where the drugs used were generic products (costing US$ 0.20 compared to US$ 0.68 in Ghana and Tanzania). However, our estimates include start-up costs and central running costs, which were excluded in the Ghana and Tanzania estimates. In Burkina Faso, a crude macro-costing of overall costs of a combined school-based and community-based national control programme

estimated the financial cost per child of providing praziquantel and albendazole to be US$ 0.32 (Gabrielli et al., 2006); although this is likely to be an underestimate because of the methodology adopted.

Regarding cost-effectiveness, Guyatt et al. (2001) estimated that the cost per anaemia (Hb<110 g/L) case prevented over 15 months as part of the Tanzania programme could be achieved at a cost of US$ 7.43 using the existing school system to deliver anthlemintics. This higher estimate is due to the higher costs mentioned above and that the intervention only reduced anaemia by 25% in Tanzania. In a study on the island of Zanzibar, Stoltzfus et al. (1998) estimated that the cost per moderate to severe anaemia case (Hb<90 g/L) averted over one year for thrice-yearly mebendazole treatment was US$ 3.57, increasing to US$ 16.30 for a case of severe anaemia averted (< 70 g/L).

Our study showed that estimates of cost and cost-effectiveness differ markedly with the total number of children treated. Specifically, average costs per child treated ranged from US$ 0.91 at an output of 7,161 children treated to US$ 0.41 at an output of 37,032 children treated. Over the same output range, delivery costs ranged from US$ 0.69 to US$ 0.19. It is also shown that cost-effectiveness increases with increasing output. Various reasons might explain the occurrence of these economies of scale. First, a number of the costs are fixed, and therefore increasing output reduces average fixed costs per child treated. Second, there is increasing ease, through better organization, learning-by-doing and more efficient processes, in implementation as the programme expands (Elbasha and Messonnier, 2004). It is possible that further expansion of the programme into more remote areas may entail diseconomies of scale due to greater transport costs and stretched administrative structures and human resources (Johns and Torres, 2005). Economies of scale have previously been documented for cancer detection programmes in the USA (Mansley et al., 2002), mass polio immunization campaigns in China (Zhang et al., 1998), vaccination sites in Bangladesh (Valdmanis et al., 2003), a national insecticide-treated net programme in Malawi (Stevens et al., 2005) and shopkeeper training programme for improving malaria home management in Kenya (Goodman et al., 2006). In the Malawian bednet programme, the scale efficiency saving were mostly related to lowering product or procurement costs (Stevens et al., 2005). Together with these studies, our findings confirm the assertion of Jabobs and Baladi (1996) that assuming constant returns to scale are unlikely to be reliable.

This study also highlights the substantial variation between districts in the cost per individual treated with praziquantel and albendazole and in cost-effectiveness. We found that the cost per schoolchild treated was lowest (US$ 0.41) in Moyo district and highest (US $ 0.91) in Masindi district. Cost-effectiveness ranged from US$ 1.70 to US$ 9.51 among districts. Because the same costing methods were used in each district, we can exclude methodological inconsistencies as a major source of variation. The results represent a first initial analysis of why costs and cost-effectiveness vary within a country. In economic terms, differences in costs may reflect underlying differences in the underlying production and cost frontiers and in the technical efficiency in delivering the intervention (Folland et al., 2004). We found that the percentage of total costs attributed to community sensitization differed across districts and was statistically associated with the delivery cost per child treated. Differences in these costs were predominantly due to the higher number of participants, especially supervisors from the district, included in the sensitization, and their allowances and salary costs. Because district officials are paid an allowance for such supervision there is an incentive for some district officials to increase the amount of supervision, possibly leading to inefficiency.

We did not observe that costs varied according to the epidemiology, geography or demography of the district. Hutton et al. (2004) found that the major determinants of the

costs of antenatal care in Cuba and Thailand were staffing patterns and productivity, where productivity was assessed using data envelopment analysis (DEA) (Charnes et al., 1995). This analytical approach was been employed by Valdmanis et al. (2003) in evaluating vaccination sites in Bangladesh where they identified levels of output which where technical inefficient as well as scale inefficient. Unfortunately, the small number of implementation units (districts) included in the present study precluded the use of DEA and so it was not possible to identify the optimal average costs and scale of operation to maximise technical efficiency. The current study needs to be repeated using larger sample sizes to quantitatively investigate the existence of technical inefficiencies. Further investigation of why costs and effects vary within different settings and between countries would also allow some judgement to be made about the relative impact of independent variables on programme costs and cost-effectiveness in a range of settings, and the extent to which cost estimates can and cannot be generalised to other settings. To guide this empirical work there is a related requirement to develop a common analytical framework for assessing cost variation (Hutton et al., 2004).

There are several qualifications in the present analysis which justify attention. First, although we have inferred that the reduction in the prevalence of anaemia was due to the intervention, one could argue that external factors may be responsible for the observed changes. Cluster-randomized trials are the accepted gold standard for evaluating health interventions delivered at the community level (Kirkwood et al., 1997). In the Uganda programme, however, it was not possible to study control cohorts of children because it was felt that a randomized controlled design, a so-called probability design (Habicht et al,, 1999), would not bear relevance to the operational reality of the national programme and would be politically difficult to implement and ethically inappropriate. As a result, there is an opportunity for chance and bias to contribute to the differences observed compared to randomized controlled trials. However, robust statistical analysis indicated that improvements in haemoglobin were largest for children who harboured the heaviest infections at baseline and that observed changes in infection patterns were in accordance with predictions arising from independently validated mathematical models of transmission dynamics (Kabatereine et al., 2007).

A second limitation is that the number of anaemia cases averted is an intermediate health outcome, which does not translate into a universally comparable health outcome measure such as deaths or disability-adjusted life years (DALYs). However, the basis for converting observed changes in patterns of helminth infection and nutrition into DALYs remains controversial (King et al. 2005; Hotez et al., 2006). To date, only one theoretical study has compared the cost-effectiveness of helminth control in relation to other programmes on the basis of DALYs (Warren et al., 1993), and this included a number of assumptions which have been subsequently questioned (Evans and Guyatt, 1995). Estimation of alternative outcome measures such as quality-adjusted life years (QALYs) remain problematic in a sub-Sahara African setting, where individuals suffer multiple health insults and are typically unable to distinguish between conditions (Kirigia, 1998; Nyandieka et al., 2002). A second alternative outcome measure is the proportion of individuals harbouring a heavy infection (Guyatt et al., 1994) since morbidity is associated with heavy infection prevalence of heavy helminth infection. WHO (2002) provides definitions of heavy infection based on the intensity of infection as assessed by faecal egg counts. However, these units are specific to individual helminth species, making the definition of a single, multiple-species threshold impossible. Comparison of the cost-effectiveness of school-based helminth control in relation to other public health interventions requires a more universal unit. The advantage of measuring cost-effectiveness in terms of anaemia is that it is an easily assessed outcome, which has been used to evaluate a number of tropical disease interventions (Stoltzfus et al., 1998; Guyatt et al., 2001; Wiseman et al. 2003; Baltussen et al. 2004). It is recognised

however that the use anaemia may miss the more subtle health benefits of deworming such as improved growth and education (King et al. 2005; Hotez et al., 2006).

There are a number of policy implications arising from this study. First, the analysis presents costs that are likely to be representative of a full-scale national programme and suggests that the programme is affordable. In particular, the cost estimates support the conclusions of earlier studies (PCD, 1998, 1999; Guyatt, 2003), which suggest that regular school-based delivery of simple and safe health interventions is a relatively low cost approach.

Second, the existence of intra-country variation in costs and variable returns to scale clearly indicates that comparison of costs and cost-effectiveness across programme settings and time periods could be misleading unless the effect of differences in input prices and output are taken into account. This is especially important in relation to forecasting costs and cost-effectiveness (Mansley et al., 2002). Many estimates of hypothetical public health programmes assume average cost will remain constant in relation to the population served (Fenwick et al., 2005; Brady et al., 2006). This assumption is, as indicated here, invalid and could lead to inaccurate cost projections. A further implication of the existence of economies of scale identified by Mansley et al. (2002) relates to comparing different interventions. Given that the cost-effectiveness is dependent on output, it is valid only to compare different interventions with similar outputs, or undertake some form of analytical adjustment to empirical estimates (Elbasha and Messonnier, 2004).

Third, the results indicate that substantial variation in intervention costs exist within a single national programme. As such, it is important to carefully consider which costs can be reliably extrapolated across different programmes. Further empirical studies coupled with the development of modelling techniques can inform future extrapolations. Such studies can also identify potential cost savings and technical efficiencies, thereby inform policy decisions and promote long-term sustainability of national programmes.

Finally, there is recent interest in the possibility of simultaneously treating a number of parasitic diseases as part of an integrated control package (Hotez et al., 2006; Lammie et al., 2006). Adding more treatments to the current programme may yield economies of scope resulting in lower average costs (Folland et al., 2004). However, this may also cause diseconomies of scope (increasing average costs), whereby adding more treatments overloads capacity and the current treatment is delivered less efficiently (Johns and Torres, 2005). This aspect deserves critical attention as integrated programmes are rolled out.

Conclusion

Economic evaluation has become a key criterion relevant for priority setting in health and in planning health care interventions. The current analysis is the first to document both the cost and cost-effectiveness of national school-based helminth control and the first to document the intra-variation in both costs and cost-effectiveness. We report the existence of economies of scale and intra-country variation in costs and in cost-effectiveness, and present an initial analysis of the causes of observed variation. The findings highlight the potential bias in transferring data across settings without understanding the nature of observed variations. Failure to do so will ultimately hinder the efficient allocation of health care resources. However, the consistency in the findings suggests that it may be possible to adjust for such variation in future analysis and the challenge remains to develop a analytical framework for understanding and assessing the extent and causes of cost variation. More evidence is clearly necessary on the cost-effectiveness of nationwide control under a range of programmatic conditions and on the underlying causes of variation in cost and cost-effectiveness.

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Appendix

resources, quantities and unit costs (Table A1)

The resources employed, the quantities consumed and unit costs are described below under the different cost centres. Many of the costs were divided equally between the school-based programme and the community-based programme, although a cost analysis is only presented for school-based treatment.

Programme running costs

The programme has a main office at the VCD headquarters in Kampala, which incurred expenses such as telephone, stationary, computers and vehicles. An estimate of the proportion of time staff at VCD in Kampala devoted to the programme. The additional resources used in making the intervention available were also estimated, including new capital costs such as vehicles, building space and equipment.

The financial cost of a new building in Kampala used to store drugs and other equipment and to house some of the programme officers was estimated on the basis of the cost of constructing and furnishing the building (US$ 87,000), annuitized using an estimated useful life of 30 years. An estimated 10% to cover annual utilities was included. The building is shared with the onchocerciasis and filariasis control programmes and therefore it was assumed that 45% of the building costs were attributable to the current programme. Between 2002 and 2005, five vehicles were purchased by the programme at a total cost of US$ 134,183. The costs of these vehicles annuitized over a useful life of 7.5 years and it was assumed that 70% of costs were attributable to programme activities. Annual expenditure on services and repairs was assumed to be 10% of annualised capital costs. Allowances of drivers and staff from the headquarters visiting districts were included in district-level cost estimates. Fuel costs to each district were calculated using MoH guidelines for distance from Kampala to specific district capitals. A computer and fax machine were also purchased at a total cost of US$ 2,245, assuming 100% allocation to the programme and a 3 year useful life. Annuitized capital costs were allocated equally across the 23 districts, attributing half the cost to school-based treatment and half to community-based treatment. Each of the districts was provided with a motorcycle at a cost of US$ 2,899 each, assumed to have a useful life of 5 years and estimated to have an annuitized cost of US$ 633, and split 50:50 between school- and community-based treatment.

Community sensitization

Prior to treatment, a series of meetings were held with community leaders and school committee members. The format of these meetings and the number of participants varied between districts. A mobile film team from MoH headquarters visited each district and showed a film in several communities to raise awareness about schistosomiasis and soil-transmitted helminths. The opportunity cost for using existing district health officials was estimated.

Training

The costs of the national training workshops were US$ 16,980 in May 2001, US$ 11,285 in November 2001, US$ 13,500 in June 2002, US$ 26,000 in December 2002, US$ 20,000 in April 2004 and US$ 22,107 in April 2005. Attended by national staff and district health staff, the workshops provided general information on schistosomiasis and STH and the national programme, as well as training on treatment registration and recording and drug administration. The total cost of these workshops is divided equally among the 26 districts, allocating half the cost to school-based treatment and half to community-based treatment. The opportunity cost for using existing district health officials for the training and the time of teachers was estimated.

In 2003, a training manual was developed by staff from VCD and SCI. The unit cost was $10.00, and ten copies were provided to each district in 2003; this cost was shared 50:50 between school-based and community-based delivery. At the district-level, the training of school teachers and community drug distributors included public awareness, drug treatment and treatment monitoring and record keeping. The expenditure for this training included trainee transport and lunch allowance, stationary (typically exercise books, pens, marking tape, permanent markers and flipcharts), district training facilitators per diem, district drivers per diem and fuel. The estimate of costs also included the per diem and fuel costs of national staff from Kampala attending the district-level training. The unit cost and quantities of each cost element varied between districts and had to be estimated separately.

Drug distribution and treatment

Praziquantel tablets were supplied by Shin Pong Pharmaceutical Company (Kyonggi, South Korea) at a unit price of US$0.072 per 600mg tablet. Assuming 2.5 tablets per child, the drug cost per child treated was US$0.18. Albendazole tablets (400mg) were supplied by International Dispensary Association (Amsterdam, Netherlands) at a unit price of US$0.023, including CIF. The Uganda National Medical Stores cleared the imported drugs and transported them to VCD headquarters in Kampala at a cost of 5% of the drug price. Drug distribution and treatment included school, drug delivery, supervision and recording of treatment, and collection of treatment registers and unused drugs. Per diems or allowances (which varied between districts) were paid to MoH staff within a district and to community health workers to perform these activities; however, teachers were not paid. Fuel and stationary costs were also estimated. The initial cost of locally produced registers to record treatment was $US 2.53 but this was subsequently reduced to US$ 1.64. In 2003 and 2004 the cost of locally manufactured height poles was $US 1.29; in 2005 modifications of the pole reduced this cost to $US 0.34. The mean treatment dose per child and adult was estimated from treatment registers. Based on experience of other programmes (PCD, 1999) and local experience, the wastage rate of drugs was assumed to be 1%. Where activities covered both school-based and community-based delivery of treatment, the costs of the activity were shared 50:50 between the two delivery systems.

Production and distribution of IEC material

Health education messages were delivered through posters, booklets, films and radio shows. Information, education and communication (IEC) material included posters, leaflets and question and answer booklets. These were developed in English and then translated into various local languages by the Health Education department of the Ministry of Health at a cost of US$ 26,000. This cost was again divided equally among the 26 districts. The distribution channel for the IEC material was the same as the drugs. In addition, an 18 minute educational video film and a five minute advocacy film was produced locally and shown widely in each district. During the treatment period, which extended from April to July, radio talk shows were aired frequently on appropriate local FM stations encouraging

people to take their drugs. The cost of these shows ranged from US$ 378.45 in Moyo district to US$ 30.68 in Masindi district. The cost elements under this cost centre were shared in the proportion 50:50 between school-based treatment and community-based treatment.

Table A1

Unit costs (and where appropriate range) of delivering anthelmintic treatment through schools in Uganda 2003-2005

Category	Input	Units	Unit cost (US$)
Capital items	Building	Per building	87,000
	Project vehicle	Per vehicle	25,000-44,304
	Computer	Per computer	1,545
	Fax machine	Per machine	700
Salaries	National coordinator	Per month	409
	National administrator	Per month	341
	Secretary	Per month	157
	Driver	Per month	63
	District VCD officer	Per month	262
	Health worker	Per month	157
	Teacher	Per month	120
	Local leader	Per month	60
Allowances	VCD (Kampala) supervisor per diem	Per day	24.70
	VCD (Kampala) driver per diem	Per day	12.87-17.90
	DVCO per diem	Per day	4.95-15.44
	Driver per diem	Per day	1.98-8.44
	Community health worker per diem	Per day	2.48-5.63
	Training workshop participant	Per workshop	1.03-3.96
Vehicle running costs	Diesel	Per litre	0.77-1.18
	Insurance	Per day	3.97
	Maintenance	Per day	8.99
Consumables	Training manual	Per manual	10
	IEC Poster	Per poster	0.45
	IEC leaflet	Per leaflet	0.14
	IEC booklet	Per booklet	0.37-0.42
	Praziquantel	Per dose	0.18
	Albendazole	Per dose	0.023
	Treatment register	Per register	1.64-2.53
	Height pole	Per pole	1.29
	Modified height pole	Per pole	0.34
Other	National workshop	Per workshop	11,285-26,000
	Radio show	Per show	30.68-378.45

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Biography

Biographies

Simon Brooker, D.Phil MSc (Econ), is an infectious disease epidemiologist and a Reader in the Department of Infectious and Tropical Disease at the London School of Hygiene and Tropical Medicine. He is currently supported by a Wellcome Trust fellowship and his research interests includes the investigation of the spatial epidemiology of parasitic diseases and the design and evaluation of intervention strategies and control programmes in resource-poor settings.

Narcis Kabatereine, PhD, is a senior entomologist with the Vector Control Division of the Ugandan Ministry of Health and programme manager of the national schistosomiasis and soil-transmitted helminth control programme. His research interests include the epidemiology and immunology of schistosomiasis, and the control of neglected tropical diseases.

Fiona Fleming, MSc, works for the Schistosomiasis Control Initiative and is the country programme manager for Uganda. She has a background in parasitology and control of infectious diseases.

Nancy Devlin, PhD, is Professor of Health Economics at City University and Senior Associate at the King's Fund, London. Her current research programme includes the development of theoretical foundations for health state valuations; models of patients' choice of health care provider; and the cost effectiveness thresholds evident from public sector decisions.

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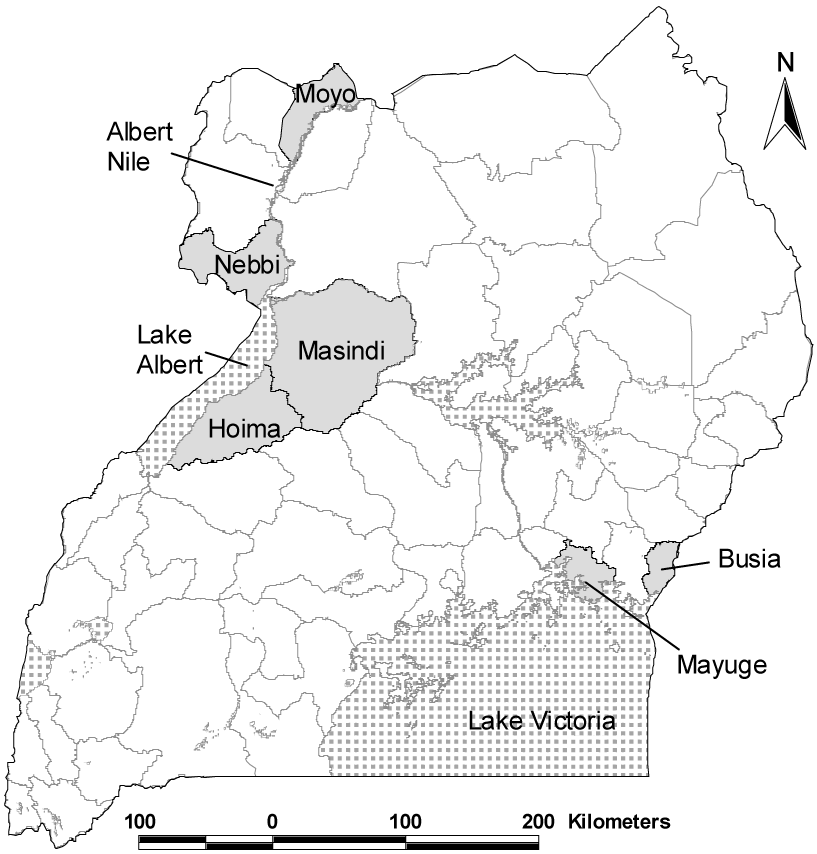

Figure 1.
Map of Uganda showing districts selected for cost analysis.

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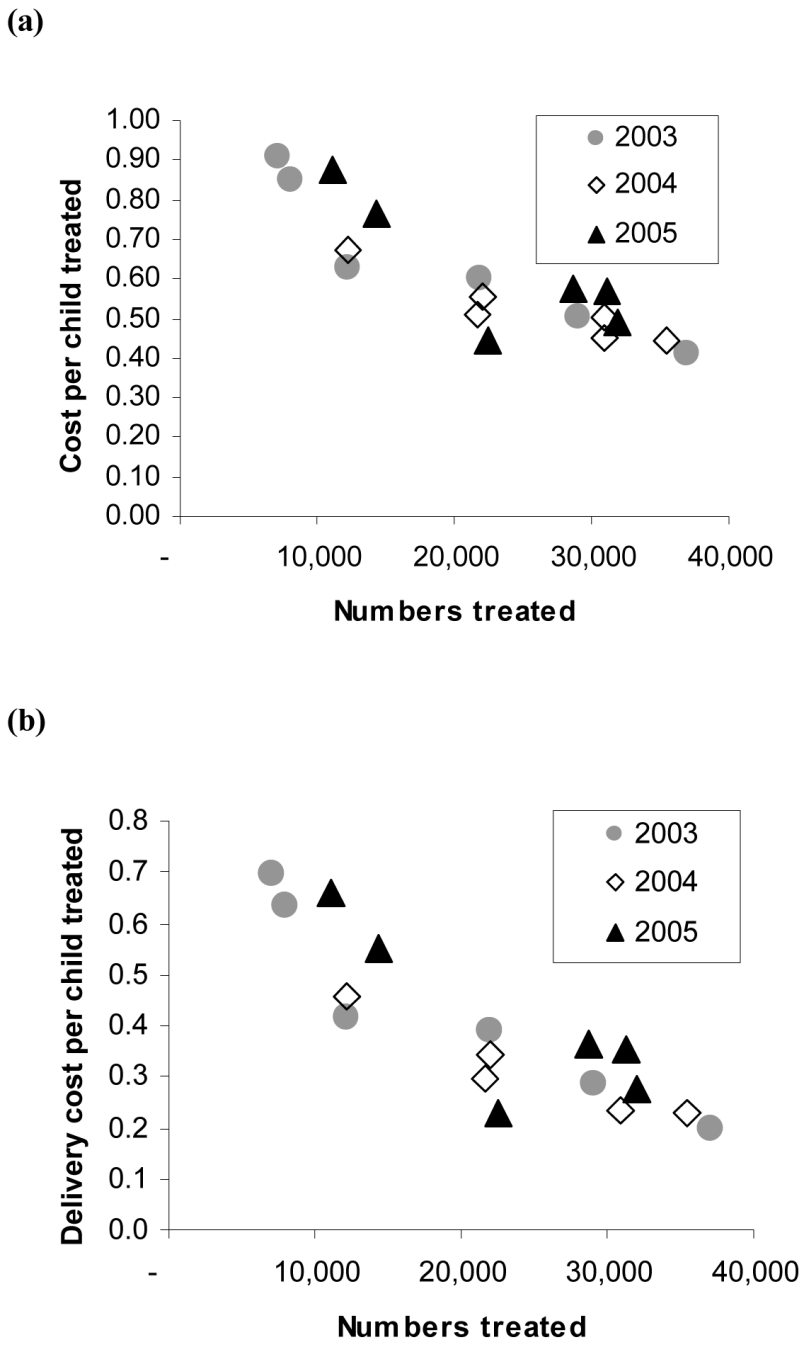

Figure 2.
(a) The relationship between output (number of children treated) and average costs (cost per child treated) and (b) the relationship between output (number of children treated) and delivery cost per child treated in six districts in Uganda, 2003-2005.

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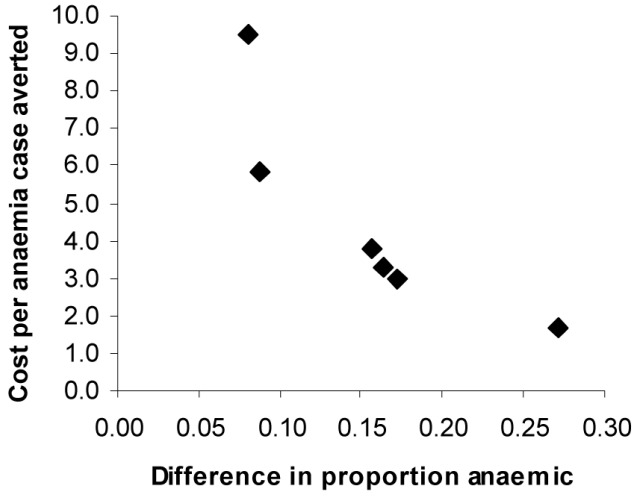
(a)



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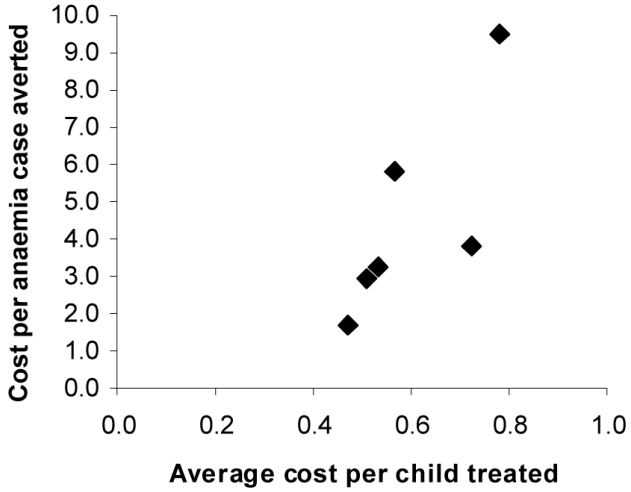

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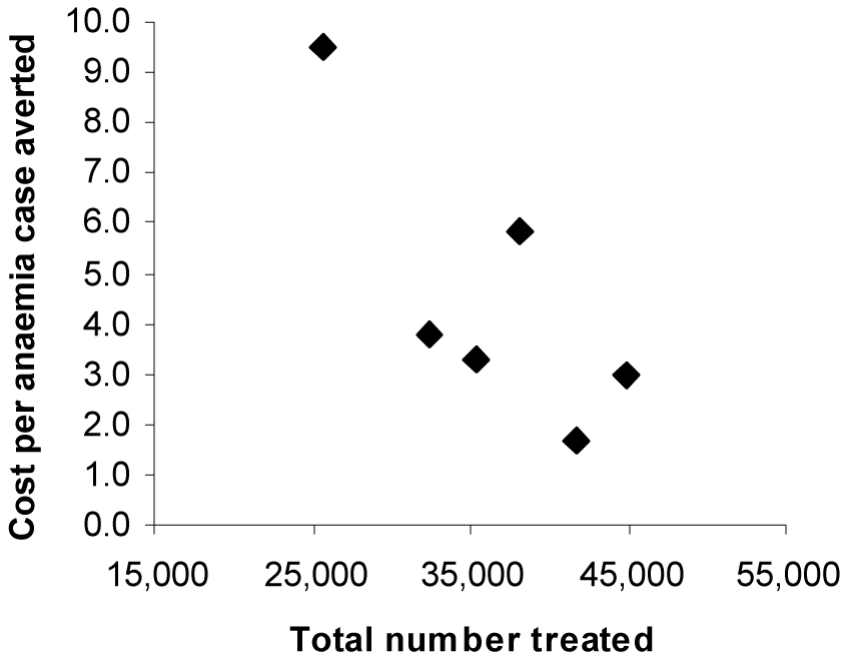

Figure 3.
(a) The relationship between economic cost per child treated and cost-effectiveness (cost per anaemia case averted); (b) the relationship between effectiveness (proportion of anaemia cases averted) and cost-effectiveness (cost per anaemia case averted); and (c) the relationship between total number of schoolchildren treated in each district over the period 2003-2005 and cost-effectiveness (cost per anaemia case averted) in six districts in Uganda.

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Table 1

Comparative economic costs (2005 US$ prices) of anthelmintic treatment by major cost centre and percentage of overall costs by district in Uganda 2003-2005.

		2003		2004		2005		Average % 2003-5
		Costs	%	Costs	%	Costs	%	
Busia	Programme running costs	526	4.0	526	4.3	526	5.3	4.5
	Community sensitization	2,349	17.8	1,984	16.1	621	6.2	13.4
	Training	2,459	18.6	1,897	15.4	688	6.9	13.6
	Drug distribution & treatment	2,531	19.1	2,761	22.5	2,594	26.0	22.5
	Imported drugs	4,701	35.5	4,722	38.4	4,815	48.3	40.7
	IEC material	658	5.0	404	3.3	721	7.2	5.2
	Total	**13,224**		**12,294**		**9,963**		
Mayuge	Programme running costs	526	7.7	526	3.3	526	5.4	5.5
	Community sensitization	2,189	32.1	1,269	8.1	455	4.6	14.9
	Training	874	12.8	1,553	9.9	3,986	40.7	21.1
	Drug distribution & treatment	1,073	15.7	2,910	18.5	2,337	23.9	19.4
	Imported drugs	1,722	25.3	7,602	48.3	2,393	24.5	32.7
	IEC material	435	6.4	1,872	11.9	91	0.9	6.4
	Total	**6,819**		**15,732**		**9,789**		
Hoima	Programme running costs	526	3.6	526	3.8	526	3.2	3.5
	Community sensitization	2,154	14.8	586	4.2	425	2.6	7.2
	Training	2,246	15.5	2,796	20.1	4,497	27.2	20.9
	Drug distribution & treatment	2,893	19.9	1,906	13.7	3,257	19.7	17.8
	Imported drugs	6,210	42.8	6,612	47.6	6,137	37.1	42.5
	IEC material	479	3.3	1,476	10.6	1,706	10.3	8.1
	Total	**14,508**		**13,902**		**16,548**		
Masindi	Programme running costs	526	8.1	526	6.4	526	4.8	6.4
	Community sensitization	2,340	36.0	1,314	16.1	1,117	10.2	20.8
	Training	585	9.0	678	8.3	3,100	28.3	15.2
	Drug distribution & treatment	1,249	19.2	1,347	16.5	1,892	17.3	17.7

		2003		2004		2005		Average % 2003-5
		Costs	**%**	**Costs**	**%**	**Costs**	**%**	
	Imported drugs	1,533	23.6	2,608	31.9	3,072	28.0	27.8
	IEC material	267	4.1	1,694	20.7	1,248	11.4	12.1
	Total	**6,500**		**8,167**		**10,955**		
Moyo	Programme running costs	526	3.5	526	4.8	526	3.4	3.9
	Community sensitization	1,944	12.8	723	6.6	615	4.0	7.8
	Training	2,235	14.7	1,445	13.1	2,031	13.0	13.6
	Drug distribution & treatment	2,218	14.6	1,443	13.1	5,283	34.0	20.6
	Imported drugs	7,928	52.1	4,627	42.0	6,837	43.9	46.0
	IEC material	352	2.3	2,246	20.4	269	1.7	8.1
	Total	**15,203**		**11,010**		**15,561**		
Nebbi	Programme running costs	526	6.8	526	3.2	526	3.0	4.3
	Community sensitization	1,771	23.1	750	4.6	802	4.5	10.7
	Training	995	13.0	1,015	6.2	4,323	24.5	14.6
	Drug distribution & treatment	1,338	17.4	6,291	38.7	4,715	26.7	27.6
	Imported drugs	2,609	34.0	6,873	42.3	6,682	37.8	38.0
	IEC material	438	5.7	781	4.8	616	3.5	4.7
	Total	**7,677**		**16,236**		**17,664**		

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Table 2

Estimated district-level economic costs (US$) per child treated by district in Uganda 2003-2005, which included valuation of staff time using full salary costs and annuitized capital costs. Figures in parenthesis indicate the estimated delivery cost per child treated (which excludes drug costs).

Area/District	2003	2004	2005
Lake Victoria			
Busia	0.60 (0.38)	0.56 (0.34)	0.44 (0.22)
Mayuge	0.85 (0.63)	0.44 (0.22)	0.87 (0.66)
Lake Albert			
Hoima	0.50 (0.28)	0.45 (0.23)	0.57 (0.36)
Masindi	0.91 (0.69)	0.67 (0.45)	0.76 (0.54)
Albert Nile			
Moyo	0.41 (0.19)	0.51 (0.29)	0.48 (0.27)
Nebbi	0.63 (0.41)	0.51 (0.23)	0.56 (0.35)

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Table 3

The proportion of cases of anaemia averted and cost per anaemia case averted as a result of the nationwide helminth control programme in Uganda, 2003-2005

Area/District	Total children treated 2003-5	Number examined	Prevalence (%) of anaemia at baseline	Prevalence (%) of anaemia follow-up	Proportion (%) of anaemia cases prevented	Financial cost (US$) per anaemia case prevented[b]
Lake Victoria						
Busia	66,507	323	27.8 (90)[a]	11.5 (37)	41.1	3.27
Mayuge	54,733	173	27.2 (47)	11.6 (20)	42.6	3.79
Lake Albert						
Hoima	88,556	210	32.9 (69)	15.7 (33)	47.8	2.95
Masindi	33,694	125	39.2 (49)	31.2 (39)	79.6	9.51
Albert Nile						
Moyo	90,580	340	42.4 (144)	15.3 (52)	36.1	1.70
Nebbi	74,282	284	39.8 (113)	31.0 (88)	77.9	5.83
Overall	**408,352**	**1,455**	**35.2 (512)**	**18.5 (269)**	**52.5**	**3.19**

[a]Number in parenthesis indicates number of cases

[b]The effectiveness of treatment with PQZ and ABZ was assessed as the number of anaemia cases prevented over the three year period, and was calculated from the difference between the proportion of children with anemia at baseline and follow-up-survey, multiplied by the number of children treated. The cost per anemia case prevented was then calculated for a thresholds for defining anaemia as <110g/L.

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Table 4

Results of one-way sensitivity analysis on the cost per case of anaemia averted of a national school-based anthelmintic treatment programme in Uganda, 2003-2005

Variation tested	Economic cost per anaemia cost averted (US$)
Base case	3.19
Discount rate 1%	3.18
10%	3.25
Reduction in drug prices 10%	3.07
20%	2.94