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RESEARCH ARTICLE

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Does subsidizing the private for-profit sector benefit the poor? Evidence from national antimalarial subsidies in Nigeria and Uganda

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Abstract

Subsidising quality-assured artemisinin combination therapies (QAACTs) for distribution in the for-profit sector is a controversial strategy for improving access. The Affordable Medicines Facility—malaria (AMFm) was the largest initiative of this kind. We assessed the equity of AMFm in two ways using nationally representative household survey data on care seeking for children from Nigeria and Uganda. First, the delivery of subsidized drugs through the for-profit sector via AMFm was compared with two alternative mechanisms: subsidized delivery in public health facilities and unsubsidized delivery in the for-profit sector. Second, we developed a novel extension of benefit incidence analysis (BIA) methods based on the concept of pass-through, and applied them to Uganda. In Nigeria, the use of subsidized QAACTs from both public health facilities and for-profit outlets was concentrated among the rich, while in Uganda, the use of QAACTs from both sources was concentrated among the poor. Similarly, the BIA of AMFm found that the intervention was pro-poor in Uganda. Unsubsidized antimalarials from for-profit outlets were distributed equally across wealth quintiles in both countries. Private sector subsidies may have a role in bolstering access to effective malaria treatments, including among the poor, but the equity impact of subsidies may depend on context.

KEYWORDS
benefit incidence analysis, equity, malaria treatment, private sector, subsidies

1 | INTRODUCTION

The private for-profit sector plays an important role in providing essential public health products in most developing countries (Grépin, 2016). Subsidization is a common approach for improving access in the private sector, and many public health products have been subsidized, including treatments for malaria, pneumonia, diarrhea, and sexually transmitted infections; water purification tablets; condoms; and bed-nets (Schäferhoff & Yamey, 2011; Taylor & Yadav, 2011).

Subsidies are contentious. One of the primary criticisms is that the private sector excludes the very poor. It is argued that any intervention that involves charging patients, even if prices are substantially reduced, will not be equitable (Kamal-Yanni et al., 2012; Morgan et al., 2016). Empirical evidence confirms that consumers of public health products are sensitive to price (Dupas, 2014) and that the poor may be disproportionately responsive (Cohen et al., 2015; Hoffmann, 2018). A number of studies have examined inequities across socioeconomic groups in the use of subsidized insecticide treated nets, antimalarial treatments, and condoms with mixed results (Alba et al., 2010; Hanson et al., 2009; Htat et al., 2015; Kangwana et al., 2011; Khatib et al., 2008; Kramer et al., 2017; Njau et al., 2009; Noor et al., 2007; Sabot et al., 2009). Challenges related to public provision of health commodities, such as stock outs, long distances to facilities, and unofficial payments, may similarly hinder access among the poor (Rahimi et al., 2019). As a result, comparative analysis across sectors can help elucidate the effectiveness of different delivery mechanisms in targeting the poor. Although some studies have compared inequality in the use of public and private providers (Campbell et al., 2016; Grépin, 2016), few studies have compared the equity of intervening in the for-profit sector, for example, through subsidization or contracting out, with public provision (Basu et al., 2012; Bhushan et al., 2002; Coarasa et al., 2017).

Comparisons of use of products obtained from different sectors are useful for describing the effectiveness of different delivery mechanisms in targeting the poor. However, retail prices may vary across groups when subsidies are distributed through the for-profit sector. Prices in the private sector are often not controlled, even when there are recommended retail prices as part of a subsidy program. Consumers may pay varying prices for a subsidized product due to the presence of local monopolies, high costs of transporting products to remote areas, or other factors affecting price. A study of the full equity implications of a subsidy, therefore, requires consideration of not only who receives the subsidized product, but also how much they pay for it.

Benefit incidence analysis (BIA), which traditionally measures how government expenditures on social services are distributed, may be appropriate for addressing this issue (Demery, 2000). BIA combines data on who uses services with data on costs, accounting for out-of-pocket expenditures (Anselmi et al., 2015). In addition, BIA methods have been modified to examine other issues like the distribution of benefits of health services provided by the private sector and geographic inequalities (Anselmi et al., 2013; McIntyre & Ataguba, 2011). To our knowledge, BIA has yet to be applied to situations where public spending is delivered through the for-profit sector.

This paper examines the equity of the Affordable Medicines Facility—malaria (AMFm), a large and controversial program, which subsidized antimalarial treatments in the for-profit sector at a national scale in seven countries in sub-Saharan Africa (Tougher et al., 2012). The empirical analysis focused on Nigeria and Uganda. These countries had rich household survey data with detailed information about antimalarial purchases that are not available from other routine surveys. This paper makes three main contributions. First, we compare the equity of subsidized delivery through private for-profit outlets under AMFm with two alternative mechanisms for delivering antimalarials to patients: subsidized delivery through public health facilities and unsubsidized delivery through the for-profit sector. Second, we take account of the prices that patients paid for subsidized antimalarials in analyzing the equity of AMFm in Uganda using a novel extension to BIA methods. Third, we extend partial identification methods to the concentration index, and thereby expand the tools available for addressing missing data when measuring health-related inequalities. The paper also assesses the suitability of a range of approaches for measuring the equity of commodity or other similar private sector subsidy interventions, and highlights the empirical challenges of applying BIA to these interventions.

2 | DESCRIPTION OF AMFm

AMFm was an innovative financing mechanism hosted by the Global Fund to Fight AIDS, Tuberculosis, and Malaria (Global Fund) from 2010 to 2012 that subsidized quality-assured artemisinin combination therapies (QAACTs), the recommended first-line treatment for malaria, at a national scale in seven countries (Ghana, Kenya, Madagascar, Niger, Nigeria, Tanzania, and Uganda). The subsidy was subsequently integrated into the Global Fund's regular financing stream (ACTwatch Group et al., 2017).

The aim of the intervention was to increase the use of QAACTs and decrease the use of other widely used but less effective treatments, thereby reducing malaria mortality and potentially delaying the onset or spread of resistance to artemisinin. The intervention was motivated by the importance of the for-profit sector in malaria treatment in many countries, and the high cost and low availability of QAACTs in this sector. AMFm had three main elements: (1) negotiations with manufacturers of QAACTs, which are artemisinin combination therapies (ACTs) that met the Global Fund's quality-assurance standards, to lower their prices; (2) co-payments of 80%–99% of the ex-manufacturer price from the Global

Fund to the manufacturers for each unit ordered by participating importers; and (3) supporting interventions, such as recommended retail prices, mass communication campaigns, and provider training. All QAACTs subsidized through AMFm had a green-leaf logo printed on the medicine's primary and secondary packaging (Tougher et al., 2012). Over 144 million doses of QAACTs were subsidized through the intervention for delivery in the for-profit sector by mid-2012.

Prior to AMFm, QAACTs delivered in the public sector of the seven intervention countries were primarily financed through Global Fund grants, and this continued during AMFm. QAACTs were officially free in public health facilities in all AMFm countries, except Ghana.

Although World Health Organization (WHO) malaria treatment guidelines have recommended universal parasitological confirmation of suspected malaria[1] through microscopy or rapid diagnostic test since 2010, AMFm did not endeavor to expand access to diagnostic testing. Availability of diagnostics varies considerably across countries, and is generally substantially lower in the for-profit sector compared to the public sector (Poyer et al., 2015). As a result, many cases of suspected malaria are treated presumptively.

An independent evaluation of AMFm assessed the effect of the intervention in improving the price, availability, and market share of QAACTs against predefined success benchmarks. The evaluation used a pre–post plausibility design, and involved baseline and endline nationally representative surveys of antimalarial outlets. Four countries met the benchmarks for QAACT availability and price, and three countries met the QAACT market share benchmark. The results were driven by substantial improvements in the private for-profit sector in all countries but Madagascar and Niger (Tougher et al., 2012).

The evaluation also examined utilization of ACTs in countries where appropriately timed household survey data were available from secondary sources. Although there were improvements over time in use among children under five with fever in three of the four countries with available data, baseline surveys were 1–2 years prior to the start of AMFm in these three countries. Factors other than AMFm may have been responsible for some of these increases (Independent Evaluation Team, 2012a).

Despite the generally positive evaluation results, the Global Fund discontinued subsidizing QAACTs for the for-profit sector in 2018 due to reductions in allocations to countries and shifting priorities (WHO, 2018). The initiative was controversial for its duration. Of particular concern was the opportunity cost of investing in the private sector, as those funds could be used to strengthen public provision, particularly since subsidies in the private sector were commonly believed to be less likely to benefit the poor (Kamal-Yanni, 2012). Information on who benefits from subsidies delivered through the private sector is therefore critical in evaluating these programs.

3 | APPROACHES FOR MEASURING THE EQUITY OF PRIVATE SECTOR SUBSIDIES

Equity analysis of the delivery of health services assesses whether the benefits of the receipt of care are unequally distributed across members of society with different living standards. Typically, the equity of delivery of health services is evaluated from a horizontal perspective to assess whether those with the same need for care receive equal treatment (Wagstaff & Van Doorslaer, 2000).

Possible approaches for valuing health care may be classified into two broad groups (see Table 1): utilization-based valuation and monetary valuation. The appropriate method will depend on the research question, and the implementation details of the subsidy intervention of interest. We now consider the suitability of these approaches for private sector subsidies in general and AMFm in particular.

In the first set of approaches, value is derived from the utilization of care (columns 1 and 2). Utilization may be measured either with a binary variable or a count of the number of services used. Regardless of how utilization is measured, benefits are constant for all that use the service. Utilization-based approaches may only be used to examine the distribution of benefits of a single service.

Utilization-based valuation has been used in equity studies of private sector subsidies of health commodities (Hanson et al., 2009; Khatib et al., 2008; Njau et al., 2009; Noor et al., 2007). Benefits are implicitly the potential health impact of using the subsidized product, and potential health impact is treated as equal for all recipients. For example, the benefits of AMFm would be the treatment of suspected malaria with a high-quality first-line drug. Utilization-based approaches are suitable for examining who, in terms of socioeconomic position, received subsidized products. However, other factors affecting the equity of a subsidy intervention, such as disparities in the costs of providing or obtaining the product, are not considered.

TABLE 1 Potential approaches for valuing public health product subsidies for equity analyses

	Utilization-based valuation		Monetary-based valuation			
			Standard BIA approaches		Pass-through-based approaches	
	(1) Binary	(2) Quantity	(3) Public sector delivery	(4) Private sector delivery	(5) Complete pass-through	(6) Price gap
Description of value	Potential health impact	Potential health impact	Net public transfers	Market price	Subsidy incidence	Subsidy incidence
Measurement	Binary variable indicating whether or not the targeted recipient received the subsidized product	Number of subsidized products obtained by the targeted recipient	Public expenditures per unit net of user fees	OOPs	Amount paid by the public funder to the for-profit provider per unit	Difference between the price the recipient would have paid for the product in the absence of subsidy and the price they paid
Type of product	Durable products (e.g., bed nets) or products where a single unit is required to treat an illness episode	Consumable products where multiple units might be purchased during a recall period (e.g., condoms)	Any; allows for aggregation across multiple products	Any; allows for aggregation across multiple products	Any; allows for aggregation across multiple products	Any; allows for aggregation across multiple products
Advantages	Requires household survey data only	Requires household survey data only	(1) Allows for variation in costs of providing the product; (2) incorporates price paid by recipients[b]	(1) Requires household survey data only; (2) based on price paid by recipients	Consistent with economic theory of the operation of subsidies	(1) Consistent with economic theory of the operation of subsidies; (2) incorporates price paid by recipients
Disadvantages	The value of the product is assumed to be equal for all recipients	The value of the product is assumed to be equal for all recipients	(1) Public expenditures must be imputed from other sources; (2) public expenditures do not necessarily reflect the value of the product	The subsidized market price is not indicative of the product's social value	Implicitly assumes perfectly inelastic demand	Counterfactual price must be imputed from other sources

TABLE 1 (Continued)

	Utilization-based valuation		Monetary-based valuation			
			Standard BIA approaches		Pass-through-based approaches	
	(1) Binary	(2) Quantity	(3) Public sector delivery	(4) Private sector delivery	(5) Complete pass-through	(6) Price gap
Appropriate for examining the equity of AMFm?	Partially; differences in the costs of providing or obtaining the product are not considered	Partially;[a] differences in the costs of providing or obtaining the product are not considered	Partially; public expenditures do not include benefits arising from the reduction in ex-manufacture prices stemming from pooled procurement negotiations	No; subsidized market price does not represent the underlying value of the product.	No; (1) assumption of perfectly inelastic demand is implausible for public health products in LMICs, including QAACTs; (2) AMFm co-payments do not include the reduction in ex-manufacture prices stemming from pooled procurement negotiations	Yes; (1) consistent with economic theory on the operation of subsidies; (2) benefits account for all aspects of the intervention, and account for variation in costs incurred to obtain the product

Abbreviations: AMFm, Affordable Medicines Facility—malaria; LMIC, low- or middle-income country; OOP, out-of-pocket expenditure; QAACT, quality-assured artemisinin combination therapy.

[a]With the available household survey data used for this study, this approach is equivalent to binary valuation. This is because the recall period is the most recent illness episode and no individuals received more than one subsidized product. [b]Out-of-pocket payments are deducted from public expenditures in benefit incidence analyses of public sector delivery of health services on the basis that fees are collected for the purpose of cost-recovery. Although this is not the case in subsidy interventions, subtracting OOP from public expenditures is justified in order to account for differences in costs incurred to access the subsidized product.

The second set of approaches quantify the benefits of health care in monetary terms. BIA combines data on the utilization of health services with estimates of the value of each service used (columns 3 and 4). BIA allows the benefit of a particular service to vary for different members of the population, and it permits aggregation across multiple services. The method used to estimate the monetary value of a service depends on the sector that delivered it. Services delivered in the public or private not-for-profit sector are valued as the costs incurred by the provider to produce the service net of user fees. Services delivered by for-profit providers are valued as the out-of-pocket expenditures (OOP) incurred to purchase the service if there is little or no insurance (McIntyre & Ataguba, 2011). However, subsidization of public health products differs from the typical delivery of health services due to the interaction between sectors. Commodities are publicly financed either through direct subsidization or vouchers, but then delivered through private for-profit wholesalers and retailers.

The standard BIA approach for health care delivered through the private sector (column 4) is not appropriate for this type of intervention. The price paid by the patient would be used to value the product. However, market price after subsidization does not reflect the underlying value of the product or the value of the subsidy, and is therefore not suitable for this type of analysis.[2]

Applying the standard BIA approach for public services (column 3) would value the benefits of the subsidized product as net public spending per unit. The advantage of this approach is that it would reflect variation in both public spending and OOP. Although there were recommended retail prices for AMFm-subsidized QAACTs, adherence to recommended prices was poor in some settings. For example, there were differences in prices of QAACTs in urban and rural areas in all of the AMFm countries at end line (Tougher et al., 2014). As a result, BIA using the typical public sector approach

might capture more fully the equity impact than a utilization-based approach. This BIA approach would be suitable for assessing the targeting of net public spending, which may be of particular interest when there is substantial variation in public expenditures due to targeting mechanisms, variations in the subsidy level, or other reasons.

The standard public-sector BIA approach is only partially appropriate for AMFm. Although it could measure variation in public expenditures required to target subsidized products to patients, in practice, there was limited data available on any such variation. While there may have been some geographical variation in the targeting of supporting interventions, like the mass media campaigns, information on the geographic coverage of supporting interventions was unavailable (Independent Evaluation Team, 2012b; Willey et al., 2013). Detailed data were available on Global Fund co-payments to manufacturers, which varied according to package size and generic formulation, with artemether–lumefantrine products receiving higher co-payments due to differences in manufacturing costs, and child packages receiving higher relative co-payments to incentivize uptake of pediatric package sizes. However, variations in co-payment levels for generic formulations do not reflect differences in the medicine quality, so the equity implications of these variations in co-payments are unclear.

Moreover, there are two main conceptual limitations to applying this approach to AMFm. First, public expenditures do not include the reductions in ex-manufacturer prices stemming from pooled procurement negotiations. Second, the distribution of QAACTs in the for-profit sector used existing supply chains, so there were no extra public expenditures related to transporting or otherwise targeting treatments to the end-user. The typical public sector BIA approach would ignore the benefits that resulted from leveraging the private sector distribution system.

The limitations of directly applying standard approaches to a private sector subsidy intervention led us to consider alternatives based on the concept of pass-through (columns 5 and 6). Pass-through is the extent to which a subsidy lowers the final price of the subsidized product. For example, 100% pass-through would imply that the market price is lowered by exactly the amount of the subsidy, while a 0% pass-through implies that there is no change in the price of the subsidized product. An advantage of using pass-through is that it values the subsidy in terms of what it intends to achieve; namely, a reduction in the market price for the subsidized product. This is consistent with how subsidies are conceptualized in tax incidence literature (Fullerton & Metcalf, 2002), and how subsidies for products that are delivered through competitive markets are measured for other purposes (Kojima & Koplow, 2015).

A standard assumption is of complete pass-through, that is, 100% of subsidies are passed on to the consumer (Fullerton & Metcalf, 2002). The underlying assumptions of the complete pass-through scenario are typically that the market is perfectly competitive, demand is perfectly inelastic, and supply is perfectly elastic. Under complete pass-through, the value of the subsidy is the amount paid by the public funder to the for-profit provider per unit. Although the underlying assumptions of complete pass-through are likely unrealistic, this assumption has been used in a range of application, such as the Commitment to Equity Assessments (Lustig, 2019).

We considered complete pass-through to be inappropriate for AMFm for three reasons. First, co-payments from the Global Fund to manufacturers likely partially reflect the reductions in ex-manufacturer prices resulting from AMFm, as negotiations with manufacturers to lower prices were also a component of the intervention. The Global Fund would have likely had to disburse higher co-payments to achieve the same ex-manufacturer price in the absence of negotiations. Due to the confidential nature of those negotiations, there is limited data on the extent to which negotiations reduced ex-manufacturer prices.

Second, the underlying assumptions of perfect competition and perfectly inelastic demand are unrealistic for markets for antimalarial medicines. There is likely imperfect competition at higher levels of the distribution chain and in retail markets in remote rural areas, and consumers of public health products are known to be sensitive to price. Third, empirical studies measuring pass-through in a variety of industries have found a range of pass-through rates, including pass-through exceeding 100% in some instances (Pless & van Benthem, 2019).

A second approach based on pass-through compares the price the patient paid with a counterfactual price that they would have had to pay in the absence of the subsidy (column 6). This approach can be viewed as a hybrid of the traditional public and private sector BIA methods. We call this the price-gap approach.

We deemed the price-gap approach as relevant for AMFm for three reasons. First, the counterfactual price provides an estimate of the benefits of delivering medicines through private sector distribution chains. Second, like the traditional public sector approach, it would incorporate variations in OOP where those that pay more for an AMFm-subsidized drug would receive lower benefits, ceteris paribus. Third, this approach is consistent with economic theory on the operation of subsidies, and is based on the observed price dynamics, rather than the simplifying assumptions of complete pass-through. However, a practical challenge is imputing a counterfactual price in the absence of experimental or quasi-experimental evidence on the effect of a subsidy on price. We explain our approach to addressing this challenge below.

4 | METHODS

4.1 | Data and setting

Nigeria and Uganda are among the 10 countries with the highest malaria burden in sub-Saharan Africa. It is the leading cause of years of life lost in Nigeria and the second leading cause in Uganda (Naghavi et al., 2017). Although access to ACTs has been increasing over time, progress in combating malaria has stalled in both countries (WHO, 2019).

Malaria treatment occurs within the context of mixed health systems with a substantial private sector role in both Nigeria and Uganda. In Nigeria, 96.9% of antimalarial sales volumes were delivered by private for-profit outlets. In Uganda, for-profit outlets accounted for 75.9% of antimalarial sales in urban areas, but only 33.0% in rural areas. The private not-for profit sector is a minor source of supply in both countries, accounting for 0.2% and 5% of sales volumes in Nigeria and Uganda, respectively (Independent Evaluation Team, 2012b). We exclude the private not-for-profit sector in the analysis and discussion that follows, because of its relatively small role in providing malaria treatment in these settings and because most interventions to improve case management are targeted to the public and private for-profit sectors.

Overall country context, indicators of the strength of AMFm implementation, and results of the AMFm evaluation are summarized in Table 2. The countries faced similar challenges to the implementation process. Both countries were affected by order rationing, which was a measure undertaken by the Global Fund from 2011 onward to reduce costs and target treatments more effectively. There were also delays in implementing mass communication campaigns in both countries.

The challenges in AMFm implementation, particularly related to the roll-out of supporting communication campaigns, likely contributed to the evaluation results in these countries. Nigeria and Uganda could be classified as medium performers, as they met some but not all success benchmarks. Both countries experienced large improvements in the availability and market share of QAACTs in the private sector. Although there was a large reduction in QAACT prices in Nigeria, prices exceeded their recommended levels and were more than three times that of other popular antimalarials. Despite the small price reduction in Uganda, the improvement in QAACT market share was substantial (ACTwatch Group et al., 2012; Independent Evaluation Team, 2012a, 2012b; Tougher et al., 2014).

To assess the equity of AMFm, we used existing datasets from nationally representative household surveys in Nigeria and Uganda that collected data on care seeking for children under five with a fever. These surveys were conducted in mid-2012 as part of the ACTwatch project, and were used as the end-line data in the independent evaluation of AMFm. The data were collected 15 and 12 months after the arrival of subsidized QAACTs in Nigeria and Uganda, respectively. The basic characteristics of the sample are described in Table 3. Full details on sampling, data collection, and other procedures for these surveys are available elsewhere (ACTwatch Group et al., 2012).

4.2 | Procedures

The equity of AMFm was assessed in two ways. First, in Uganda and Nigeria, the utilization-based valuation approach was used to compare subsidized delivery of QAACTs through the private sector (i.e., AMFm) with officially free delivery of QAACTs through the public sector, and unsubsidized delivery of antimalarials through the for-profit sector. Second, in Uganda, the benefit incidence of AMFm was measured using a price-gap approach, and compared to the utilization-based approach. BIA was completed for Uganda only, due to the low overall use of AMFm-subsidized QAACTs in Nigeria and the high degree of missing price data.

4.2.1 | Identifying beneficiaries of antimalarial distribution mechanisms

The ACTwatch household surveys recorded details on every antimalarial obtained, including its source, to treat a child under five that had a fever in the preceding 2 weeks. Information about the antimalarial's brand and generic name was either copied by interviewers directly from packaging in cases where it was available (47.4% [Nigeria] and 23.6% [Uganda] of antimalarials) or based on caregiver recall with the assistance of a comprehensive visual aid. Antimalarials were classified as non-artemisinin therapies, artemisinin monotherapies, and ACTs based on active ingredients. ACTs were further classified as QAACTs and non-quality-assured ACTs based on the brand name following the approach used in the AMFm-independent evaluation (Independent Evaluation Team, 2012b; Tougher et al., 2012). The detailed brand name

TABLE 2 Context, process of implementation, and evaluation results of AMFm in Nigeria and Uganda

	Nigeria	Uganda
Context		
World Bank income classification	Lower–mid	Low
Population (millions)	158.0	33.4
Rural population as % of total	80.1%	55.6%
Public-sector user fees	Yes	No
Out-of-pocket expenditure (% of current health expenditure)	76.6%	38.4%
Population at risk of malaria	100.0%	100.0%
Antimalarial sales that went through the for-profit sector before AMFm	96.9%	39.5%
AMFm implementation		
Doses delivered per person at risk of malaria through the for-profit sector [to end 2011]	0.32	0.21
% Of orders approved by the global fund under order rationing [to end of 2011]	24%	57%
Months of communications campaign at scale to midpoint of endline independent evaluation outlet survey	3	0
Summary of evaluation results from the for-profit sector		
Percentage point change in QAACT availability (95% CI)	26.3 (15.1–37.5)	54.2 (47.3–61.0)
Change in median QAACT price per AETD (p-value)	−$2.99 ($p < 0.01$)	−$0.83 ($p = 0.265$)
Percentage point change in QAACT market share (95% CI)	15.6 (12.1–19.1)	33.4 (26.0–40.8)
Summary of evaluation results for ACT use (all sectors)		
Percentage point change in use of ACTs among febrile children <5 (95% CI)	6.7% (4.2–9.2)	24.0% (15.5–32.5)

Notes: User fees refer to the presence of any user fees in the public sector. Malaria case management is free for children <5 in both countries. Source: Independent Evaluation Team (2012a, 2012b); ACTwatch Group et al (2012); World Health Organization (2021); World Bank Group (2018).

Abbreviations: AETD, adult-equivalent treatment dose; AMFm,Affordable Medicines Facility—malaria; CI, confidence interval; QAACT, quality-assured artemisinin combination therapy.

TABLE 3 Households visited for the ACTwatch 2012 household surveys

Country	Selected enumeration areas	Households screened	Eligible households[a]	Number of children <5 with fever
Nigeria	76	7863	1312	1551
Uganda	248	5067	1832	2273

[a]Eligible households were households with a child under five that had a fever in the previous 2 weeks. Source: ACTwatch Group et al. (2012).

information collected in the ACTwatch surveys is not collected in other routine household surveys, and made it possible to distinguish subsidized QAACTs from other ACTs. We show a breakdown of antimalarials by drug type and outlet source in Table SA1.

Beneficiaries of AMFm were febrile children that received a QAACT from a for-profit outlet, while beneficiaries of public sector delivery of were children that received a QAACT from a public source. We assumed that all QAACTs received from a private source were subsidized through AMFm, as market share of unsubsidized QAACTs in the for-profit sector was low. From outlet surveys that involved a comprehensive audit of antimalarials stocked conducted from 2011 to 2012, market share (for all age groups) of unsubsidized QAACTs in the for-profit sector was 1.4% in Nigeria and 4.8% in Uganda, while market share of subsidized QAACTs was 16.4% in Nigeria and 33.7% in Uganda (Independent Evaluation Team, 2012b).[3] Beneficiaries of unsubsidized delivery of antimalarials were children with febrile illness treated with any antimalarial from a for-profit outlet that was not subsidized by AMFm. This includes non-quality-assured ACTs, artemisinin monotherapies, and non-artemisinin therapies. A child may have received multiple antimalarials, and therefore could be classified as a beneficiary of more than one distribution mechanism.[4] We examined the sensitivity of the results to different assumptions about whether QAACTs missing logo information were subsidized by AMFm. Further details on this sensitivity analysis may be found in the Appendix.

4.2.2 | Calculation of the price-gap

The price gap was defined as the difference between the counterfactual price, which is the price households would have paid in the absence of the AMFm subsidy, and the price the household paid to obtain the AMFm-subsidized QAACT. We did not have experimental or quasi-experimental data to calculate a counterfactual reference price, which would have been preferred. Instead, we used the median price for QAACTs from the baseline outlet survey conducted as part of the AMFm-Independent Evaluation as the counterfactual price (Tougher et al., 2012). We did not compare the benefit incidence of the private component of AMFm with the benefit incidence of public delivery of QAACTs, because the required data on government expenditures related to distribution of QAACTs were not available.

There was low item response on the price that the household paid to purchase an antimalarial. Drug purchase price was observed for approximately 55% of AMFm-subsidized ACTs obtained from a private for-profit source. However, respondents were also asked to provide the total cost of treatment at the source where the drug was obtained. Many respondents that could not recall drug price were able to provide the total cost of treatment (see Table SA1).

The missing data mechanism, that is, the relationship between missing values and observable and unobservable characteristics, determines the solutions that are appropriate for addressing missing data problems. We summarize missing data mechanisms in the Appendix. We use two approaches for addressing the missing data problem. First, we assume that price data were missing at random (MAR), and impute missing data using multiple imputation by chained equations with predictive mean matching. A complete case analysis will be biased, as the variables that are associated with whether price was observed are not included in the convenient regression used to estimate the concentration curve (Sterne et al., 2009).[5] Predictive mean matching was selected for the imputation model because it preserves the distribution of the observed data and observed prices were not normally distributed. The imputation model included a variable for the child's fractional rank of the socioeconomic status (SES) variable, drug and household characteristics associated with whether price was observed, variables associated with the level of price, including the total cost of treatment, and a set of cluster dummy variables. Forty-five imputed datasets were created.

Second, we extended the partial identification approach of computing best- and worst-case bounds of the concentration index based on the work of Manski (2005). The advantage of this approach is that it requires no assumptions regarding the missing data mechanism, and is therefore compatible with missing not at random (MNAR) data. To our knowledge, this is an innovative extension of the partial identification approach to the concentration index and the first analysis of the concentration index allowing for an MNAR mechanism (Zhong, 2010). A detailed explanation of our approach for computing the bounds is found in Appendix (Section A.3).

4.2.3 | Measuring equity

We adopted a horizontal equity perspective. We considered all febrile children with suspected malaria as having the same need for malaria treatment. A child was suspected to have malaria if they had a recent fever and had either a positive malaria parasitological test or no test. Inequities were measured using the concentration index. Socioeconomic position was measured using a wealth index constructed at the level of the household using principal component analysis and standardized in relation to a standard normal distribution (Littrell et al., 2011). The concentration index was computed using the convenient regression method (O'Donnell et al., 2008).

The concentration indices for binary variables (i.e., utilization) were corrected using the procedure suggested by Wagstaff (2005). The concentration index for a binary variable is bounded by its mean. As mean utilization of the three antimalarial delivery mechanisms differed substantially within and across the study countries, the Wagstaff correction was selected to facilitate comparison. An alternative correction proposed by Erreygers (2009) is also appropriate for binary variables. As there is no clear consensus on the preferable correction method and the corrections impose differing value judgments, we also report results with the Erreygers correction in the Appendix (Kjellsson and Gerdtham, 2014). The concentration index for benefit incidence is the standard (uncorrected) concentration index, so for comparison purposes, we also present the standard concentration index for the utilization of QAACTs alongside the BIA results. We also present the standard concentration index for the other delivery mechanisms in the Appendix to allow for comparison with older studies and those published outside of the economics literature.

p-Values test the null hypothesis that the concentration index is equal to zero (O'Donnell et al., 2016). All analyses are weighted with sample weights, and account for clustering at the level of the primary sampling unit (locality in Nigeria and sub-county in Uganda).

5 | RESULTS

5.1 | Malaria treatment-seeking behavior

Treatment-seeking behavior for children with recent febrile illness after more than 1 year of AMFm implementation is shown in Figure 1. We report whether children received a malaria parasitological test, an antimalarial, and a composite indicator of receiving any malaria case management. The composite indicator (shown in green) measures whether the child received either a parasitological test or an antimalarial treatment, as children that had a negative test would ideally not receive an antimalarial medicine. Parasitological testing was low in both countries. Less than 10% of febrile children in Nigeria had a parasitological test, and there were no significant differences between the poorest quintile and the other quintiles. Malaria parasitological testing was higher overall in Uganda, and was 11.1 percentage points higher in the least poor quintile compared to the poorest quintile. In Nigeria, children in the poorest quintile were less likely to receive an antimalarial or case management in the form of diagnosis or treatment compared to children in the fourth and least poor quintile. In Uganda, this relationship was reversed; children in the poorest quintile were more likely to have received an antimalarial or some form of malaria case management in the form of a test or antimalarial.

The proportion of febrile children that were treated with antimalarials obtained through the three delivery mechanisms is shown in Figure 2. The results reveal different treatment-seeking patterns across the two study countries. The unsubsidized private for-profit sector was the most popular source of antimalarials across all quintiles in Nigeria with 24.2% of febrile children receiving an unsubsidized antimalarial from a for-profit outlet, and there were no differences across quintiles in the overall use of this delivery mechanism. Use of subsidized QAACTs from either a public or for-profit source was considerably lower than unsubsidized delivery in Nigeria across all quintiles, and compared to use of subsidized delivery in Uganda. Use of subsidized QAACTs from either source was higher in the least poor quintile compared to the poorest.

The subsidized private sector was the largest source of treatment in Uganda overall, where 21.5% of febrile children received an AMFm-subsidized QAACT, and the use of this mechanism was higher in the poorest quintile compared to the least poor. 17.2% of febrile children received a QAACT from a public health facility, and the use of this mechanism was also higher in the poorest quintile compared to the least poor. 13.2% of febrile children received an unsubsidized antimalarial from a for-profit outlet, and there were no differences across quintiles in the use of unsubsidized antimalarials.

Prices paid for antimalarial treatments obtained from the for-profit sector also vary by socioeconomic position (Table 4). This is partially driven by choice of antimalarial type. Antimalarials obtained from the for-profit sector were divided into three categories: QAACTs, non-artemisinin therapies, and other antimalarials, which is composed of unsubsidized ACTs and artemisinin monotherapies. Other antimalarials were more expensive than QAACTs and non-artemisinin therapies and were purchased less frequently in both countries, but the few that were procured tended to be purchased by households with a higher socioeconomic position. Within treatment types, there was also some evidence of a relationship between the price paid and socioeconomic position. In Uganda, there was a positive relationship between the price paid for an AMFm-subsidized QAACT and socioeconomic position, with those with a higher SES paying more to receive an AMFm-subsidized QAACT ($p = 0.001$). This appears to be driven by the least poor quintile, where the median price was much higher at US$ 1.21 compared to medians of US$ 0.24–0.49 in the other four quintiles. We could not assess this for Nigeria, due to the low overall use of AMFm-subsidized QAACTs.

There is also some evidence of a positive relationship between price and socioeconomic position for non-artemisinin therapies in both Nigeria ($p = 0.052$) and Uganda ($p = 0.065$). In Uganda, this is again driven by a higher median price of US$ 1.42 among the least poor quintile compared to the other four quintiles, where median prices for non-artemisinin therapies ranged from US$ 0.28–0.81. In Nigeria, median price was lower in the poorest quintile (US$ 0.61) compared to the other four better-off quintiles which had the same median price of US$ 0.92. Given that there seems to be an association between a household's socioeconomic position and the price they paid to obtain subsidized QAACTs in the for-profit sector, this highlights the relevance of price to an equity analysis. Due to the low use of AMFm-subsidized QAACTs in the private sector in Nigeria, we only present the results for the benefit incidence of AMFm for Uganda in the analysis that follows.

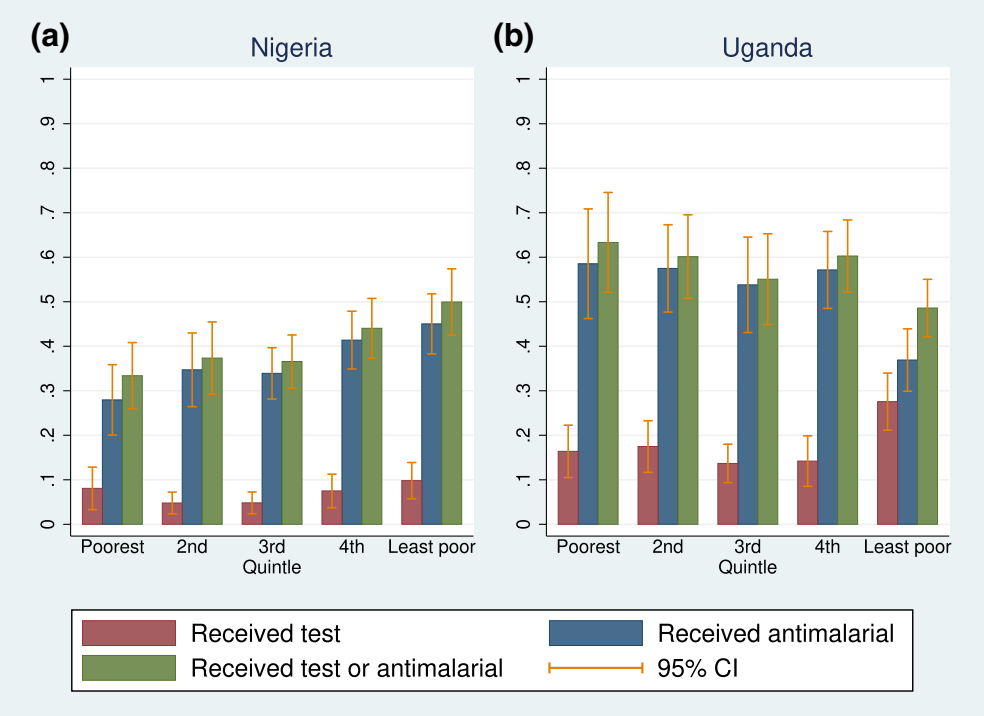

FIGURE 1 Use of malaria parasitological tests and antimalarials from any source by quintile. Denominator is all children <5 with recent febrile illness (1551 children in Nigeria and 2273 in Uganda). Proportions were weighted to reflect the complex survey design, and confidence intervals were adjusted for clustering [Colour figure can be viewed at wileyonlinelibrary.com]

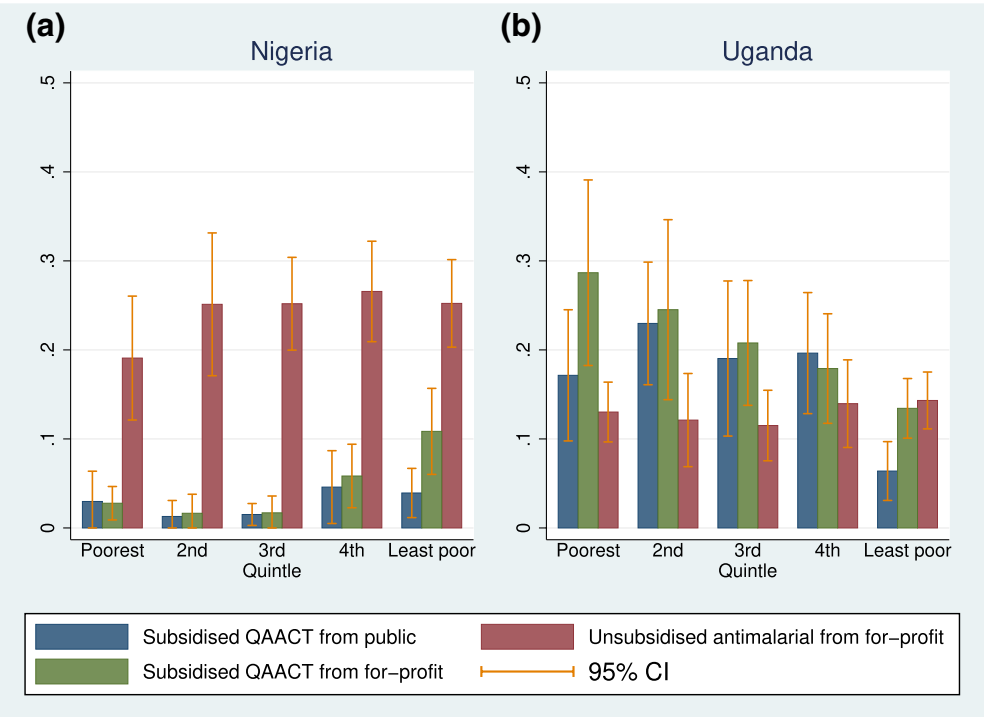

FIGURE 2 Use of antimalarials delivered through the public sector and subsidized and unsubsidized private for-profit sector. Denominator is <5 children with recent febrile illness (1551 children in Nigeria and 2273 in Uganda). Proportions were weighted to reflect the complex survey design, and confidence intervals were adjusted for clustering. QAACT, quality-assured artemisinin combination therapy; CI, confidence interval [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 4 Price paid for antimalarial treatments in the for-profit sector by quintile in Nigeria and Uganda

	AMFm-subsidized QAACTs				Non-artemisinin therapies				Other antimalarials			
	Median	[IQR]	*p*	*N*	Median	[IQR]	*p*	*N*	Median	[IQR]	*p*	*N*
Nigeria												
Poorest quintile	ns	-	ns	2	0.61	[0.37–0.92]	0.052	28	ns	-	ns	1
Second quintile	ns	-		1	0.92	[0.37–1.23]		50	ns	-		4
Third quintile	ns	-		1	0.92	[0.61–1.23]		45	2.58	[2.45–3.68]		7
Fourth quintile	1.23	[0.92-1.23]		8	0.92	[0.74–1.53]		54	ns.	-		4
Least poor quintile	0.92	[0.92-1.23]		16	0.92	[0.61–1.23]		38	3.37	[2.15–3.99]		11
Total				28				215				27
Uganda												
Poorest quintile	0.40	[0.20–0.81]	0.001	76	0.40	[0.20–1.21]	0.065	21	0.61	[0.40–0.81]	ns	7
Second quintile	0.49	[0.16–0.97]		51	0.28	[0.12–1.42]		17	ns	-		4
Third quintile	0.24	[0.20–1.01]		32	0.81	[0.24–1.21]		24	ns	-		4
Fourth quintile	0.40	[0.32–0.81]		44	0.28	[0.20–0.40]		36	ns	-		4
Least poor quintile	1.21	[0.73–1.21]		59	1.42	[0.81–1.82]		37	3.64	[1.62–6.07]		13
Total				262				135				32

Notes: Median price and IQR were not shown if there were less than five observations per quintile. *p*-Values were not shown if there were less than 40 observations for a drug category overall. *p*-Values are from an OLS regression of fractional rank on antimalarial price. Medians were weighted to reflect the complex survey design, and *p*-values adjusted for clustering.

Abbreviations: IQR, interquartile range; QAACT, quality-assured ACT; ns, not shown.

5.2 | Equity analysis of AMFm

5.2.1 | Utilization-based valuation

Figure 3 illustrates inequities in the use of antimalarials obtained through different mechanisms using the concentration curve, while the concentration index is shown in Table 5. This analysis includes only children with suspected malaria,[6] as they are assumed to have a similar need for malaria treatment, rather than all febrile children. Unsubsidized antimalarials from for-profit outlets were distributed equally in both countries ($p = 0.178$ in Nigeria and $p = 0.418$ in Uganda).

The equity findings differed between the two countries for use of subsidized antimalarials from both the public and private sectors. In Nigeria, the use of subsidized QAACTs from private for-profit outlets was concentrated among the rich ($p = 0.002$). The use of QAACTs from public health facilities in Nigeria also appears to be concentrated among the rich, although the concentration index is not statistically significant ($p = 0.220$). In Uganda, the use of subsidized QAACTs from these sources was concentrated among the poor ($p = 0.026$ for QAACTs from public health facilities and $p = 0.029$ for QAACTs from for-profit outlets). However, visual inspection of the public-sector concentration curve shows that it closely follows the line of equality until approximately the 40th percentile where it begins to bow outwards indicating equal use among the poorest two quintiles and then relatively higher use among children with a higher socioeconomic position.

We examined whether these results were sensitive to the methods for correcting the concentration index. Applying the Erreygers (2009) method substantially lowers the point estimates for the concentration indices for subsidized QAACTs from for-profit outlets or public health facilities in Nigeria, due to the low use of these distribution mechanisms.

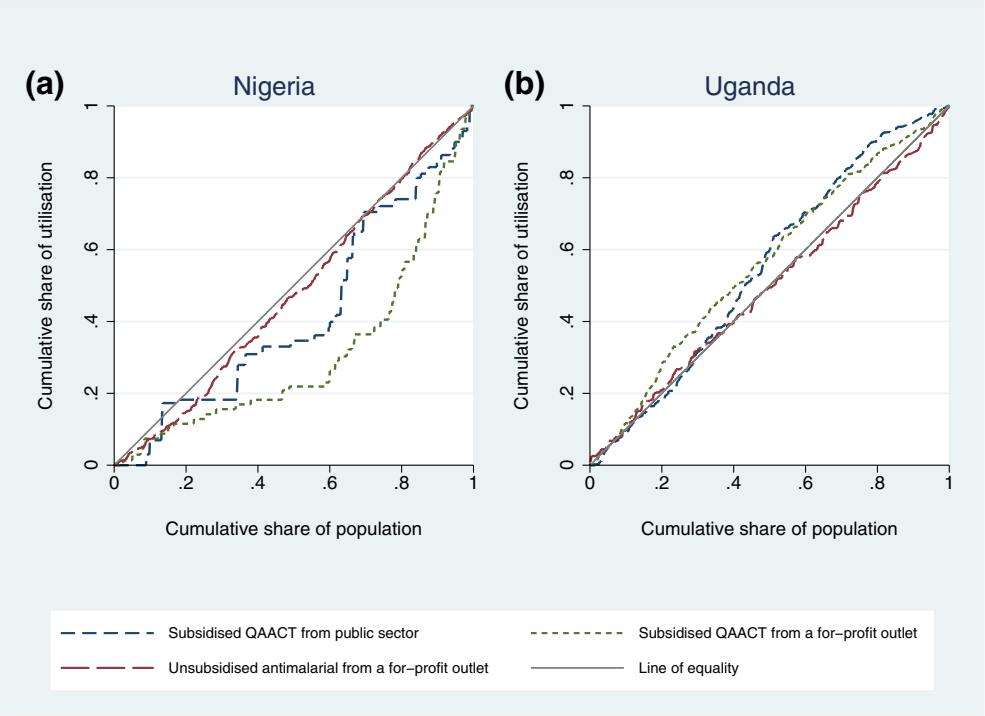

FIGURE 3 Concentration curves for the use of alternative antimalarial distribution mechanisms to treat children <5 for suspected malaria. Children with suspected malaria are defined as children with recent febrile illness that either had a positive parasitological test or did not receive a test. In Nigeria, there were 1503 children with suspected malaria, of which 38 received a subsidized QAACT from a public facility, 61 received a subsidized QAACT from a for-profit outlet, and 372 received an unsubsidized antimalarial. In Uganda, there were 2119 children with suspected malaria, of which 341 received a subsidized QAACT from a public facility, 478 received a subsidized QAACT from a for-profit outlet, and 299 received an unsubsidized antimalarial from a for-profit outlet (Ns unweighted) [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 5 Inequities in the use of antimalarials delivered through the public sector and subsidized and unsubsidized private for-profit sector by children <5 with suspected malaria

	Use of subsidized QAACTs from public health facilities		Use of subsidized QAACTs from for-profit outlets		Use of unsubsidized antimalarials from for-profit outlets	
	***C* (SE)**	***p***	***C* (SE)**	***p***	***C* (SE)**	***p***
Nigeria	0.17	0.220	0.39	0.002	0.06	0.178
	(0.136)		(0.123)		(0.042)	
Uganda	−0.13	0.026	−0.16	0.029	0.03	0.418
	(0.058)		(0.069)		(0.035)	

Notes: C was adjusted according to the method in Wagstaff (2005). *p*-Value is for the null hypothesis that the concentration index is 0. Children with suspected malaria are defined as those that had recent febrile illness and either a positive parasitological test or did not receive a test. In Nigeria, there were 1503 children with suspected malaria, of which 38 received a subsidized QAACT from a public facility, 61 received a subsidized QAACT from a for-profit outlet, and 372 received an unsubsidized antimalarial. In Uganda, there were 2119 children with suspected malaria, of which 341 received a subsidized QAACT from a public facility, 478 received a subsidized QAACT from a for-profit outlet, and 299 received an unsubsidized antimalarial from a for-profit outlet (Ns unweighted).

Abbreviations: *C*, concentration index; SE, standard error.

However, choice of method of correction does not affect the ranking of distribution mechanisms in terms of which is the most inequitable in each country or statistical significance (Tables SA2 and SA3).

5.2.2 | Benefit incidence analysis

Table 6 shows the inequality in the benefit incidence of the private sector component of AMFm using the price-gap approach in Uganda. We do not present the BIA results for Nigeria, due to the low use of the AMFm distribution mechanism and low reporting of price.

The point estimates from the multiple imputation approach for addressing missing data indicate greater (pro-poor) inequality for private for-profit QAACT distribution than those from the utilization-based valuation, which is consistent with what one would expect based on the price results in Table 4. In other words, if the MAR assumption is correct, richer households pay more for AMFm-subsidized drugs than poorer households. However, the concentration index is no longer statistically significant ($p = 0.137$) with multiple imputation, reflecting the uncertainty introduced by the missing data.

The partial identification bounds shown in Table 6 are also illustrated in Figure SA1 and discussed in more detail in Appendix (Section A.4). The distribution of benefits is pro-poor for all possible values of the missing data. Using total treatment cost data to restrict the range of possible values of the missing data narrows the bounds considerably. Nevertheless, the upper bound estimate for the BIA exceeds the utilization-based valuation, even when the total treatment cost data are used to restrict the range of possible values of the missing data. This means there are plausible configurations of the missing data where the benefit incidence of AMFm is less pro-poor than the utilization-based valuation. This is shown with shading in Figure SA1.

The width of the partial identification bounds, and the size of the standard errors relative to the point estimate of the concentration indices in the multiple imputation analysis highlight the importance of considering missing data when undertaking an equity analysis.

5.3 | Robustness to different assumptions for identifying AMFm-subsidized QAACTs

We examined the robustness of our results to our assumption that all QAACTs purchased in the private for-profit sector were subsidized through AMFm in Tables SA4–SA9. The results are generally similar to the core results, and any variations are minor and do not affect the overall conclusions of this study. In the description of malaria treatment seeking patterns by quintile, the unsubsidized commercial sector becomes the dominant source of treatment in both countries when alternative assumptions are used to classify QAACTs purchased in the private sector. However, patterns of use across quintiles are similar to the main results (Table SA4). Results related to pricing are robust in the first scenario (Table SA5), but not to the second, albeit less plausible, assumption about which QAACTs were subsidized (Table SA6).

All results from the equity analysis are robust to different assumptions used for identifying subsidized QAACTs in the private sector (Tables SA7–SA9), with the exception that the distribution of unsubsidized antimalarials in the for-profit sector becomes marginally pro-rich in Nigeria when all QAACTs missing the logo information are classified as subsidized by AMFm. However, the unsubsidized for-profit sector remains more equitable than the subsidized public and for-profit sector (see Table SA7), which is consistent with the main findings.

6 | DISCUSSION

We have presented results from two approaches to assess the equity of AMFm. First, we compared the equity of delivering subsidized QAACTs in the for-profit sector with that of alternative mechanisms for distributing antimalarials to patients: subsidized delivery through public health facilities, and unsubsidized delivery in the for-profit sector. Second, we extended the methods of BIA to examine subsidizing the for-profit sector and compared our BIA approach to the typical utilization-based valuation approach. We consider the policy implications of the results and the methodological contributions and limitations in turn below.

TABLE 6 Inequities in utilization and benefit incidence of AMFm in private for-profit outlets in Uganda

	Utilization-based valuation		BIA									
			Multiple imputation		Partial identification bounds (wide)				Partial identification bounds (narrow)			
					Lower bound		Upper bound		Lower bound		Upper bound	
	C (SE)	*p*	*C* (SE)	*p*	*C* (SE)	*p*	*C* (SE)	*p*	*C* (SE)	*p*	*C* (SE)	*p*
Uganda	−0.12 (0.054)	0.029	−0.20 (0.133)	0.137	−0.34 (0.077)	0.0001	−0.03 (0.066)	0.699	−0.26 (0.065)	0.0002	−0.07 (0.062)	0.246

Notes: C for utilization is not corrected using the Wagstaff (2005) method for the purpose of comparison with the BIA results. *p*-Value is for the null hypothesis that the *C* is 0. Narrow bounds use data on the total cost of treatment to calculate the minimum plausible benefit of AMFm for when it was observed. The minimum benefit of AMFm is 0 when calculating the wide bounds. There were 2119 children with suspected malaria in Uganda, of which 478 received a subsidized QAACT from a for-profit outlet (Ns unweighted).

Abbreviations: *C*, concentration index; SE, standard error.

6.1 | Summary and policy implications

Our comparison of the different mechanisms for delivering antimalarials to patients provides evidence pertinent to long-standing debates on the relative merits of public or private delivery of health services. We found that the unsubsidized private sector was used equally across households, regardless of SES. This is perhaps surprising, as one might expect that the poorest households could not afford any antimalarial medicine from the for-profit sector. A major concern, however, is that patients, especially those in poorer households, are purchasing less expensive and less effective treatments. The vast majority of treatments purchased in the unsubsidized commercial sector were non-artemisinin therapies, which are not the recommended first-line treatments.

The distribution of subsidized QAACTs through both public and for-profit outlets was pro-poor in Uganda and pro-rich in Nigeria. The results for Nigeria were particularly striking. Few children received QAACTs from either a public or private source, and those that did were concentrated among wealthier households.

Pro-poor distributions in the use of health commodities are uncommon. For example, a 30-country study that examined inequality in a range of malaria control interventions, including bed-net ownership and treatment of febrile children with a first-line antimalarial, found 6 countries with a pro-poor distribution of first-line treatments and no countries with a pro-poor distribution of bed-nets (Galactionova et al., 2017). The findings that the distribution of AMFm-subsidized QAACTs was pro-poor in Uganda were especially surprising, as Uganda was the weakest performer in terms of reductions in prices of QAACTs of all the AMFm countries (Tougher et al., 2012). The results highlight the importance of undertaking empirical investigation, rather than making assumptions about the behavior of households and the equity of interventions.

The novel application of BIA to AMFm provides further insight into the equity of the intervention. BIA in the health sector is typically used to assess equity in the distribution of public spending delivered through public health facilities. This is the first study to our knowledge that sought to apply these methods to a context where public (i.e., donor) funding was delivered through for-profit outlets. We considered the various approaches for valuing the benefits of such an intervention, and applied the approach that was most relevant to AMFm. The price-gap approach allowed us to see whether there were systematic differences in the prices paid by households to obtain a subsidized treatment, which might be anticipated if poorer households pay higher prices due to high transportation costs or lack of competition in remote areas. Although this aspect of the analysis was complicated by high levels of missing drug cost data, AMFm remains pro-poor under the price-gap approach. However, whether patients from poorer households pay more for AMFm-subsidized drugs depends on the missing data mechanism. Under an MAR assumption, the price-gap valuation was more pro-poor than the utilization-based approach. Nevertheless, there was a limited set of plausible configurations of the missing data under MNAR where the price-gap valuation is less pro-poor than the utilization-based valuation, indicating that it is possible that poorer households paid relatively more for AMFm-subsidized drugs compared to better-off households.

We adopted a horizontal equity perspective, which deems allocations where those with the same healthcare need (suspected malaria) receive the same services (antimalarial treatment) regardless of socioeconomic position as equitable. However, households have different abilities to pay. Therefore, while there may have been equal use of the unsubsidized for-profit sector in both countries and pro-poor use and benefit incidence of subsidized QAACTs in Uganda, the use of

these distribution mechanisms likely place a larger burden on poorer households due to their lower ability to pay. In other words, our results do not address the progressivity of out of pocket payments in the for-profit sector. This caveat should be kept in mind when interpreting the results.

The major policy implications of these results are twofold. First, the results demonstrate that interventions involving the private for-profit sector do not necessarily exclude the poor. Engagement with the private sector is important to improve the quality of case management, given the large numbers of patients that access care in that sector. Second, subsidizing treatments in the for-profit and public sectors is not sufficient to ensure universal access to quality first-line drugs. This was especially evident in Nigeria where very few children received a QAACT from either a public or private source. Households, including the poor, may have continued to purchase non-artemisinin therapies from for-profit outlets for several reasons. First, although availability of QAACTs increased in the private sector in both countries, it was not universal. In Nigeria, drug shops are responsible for the vast majority of antimalarial sales in both urban and rural areas. However, only 54.2% of drug shops in Nigeria were found to stock QAACTs at end line in the AMFm evaluation. In Uganda, availability of QAACTs was 80.9% in the for-profit facilities and pharmacies that were the dominant providers in urban areas, but only 58.0% in the rural drug shops that were the dominant for-profit provider in rural areas (Tougher et al., 2012). Second, public health facilities sometimes face stockouts or charge unofficial fees for treatment which may explain the pro-rich distribution of public sector QAACT delivery in Nigeria. For example, more than 40% of public health facilities in both urban and rural areas in Nigeria did not have a QAACT in stock at the time of the AMFm end-line evaluation. Although malaria treatment is officially free in the public sector in both countries for children under five, some households in Nigeria reported paying for malaria treatment obtained in the public sector. Such informal payments were higher in value among patients in the poorest quintile compared to the other quintiles (data not shown). Third, patients may prefer non-artemisinin therapies over ACTs due to familiarity with this older class of drugs or for other reasons.

The generalizability of these results to the other AMFm countries is unclear. Prices for subsidized QAACTs relative to the most popular non-artemisinin therapies were higher in Nigeria and Uganda than any of the other settings. Consequently, the equity of AMFm in other countries may have differed. For example, in Kenya, prices of QAACTs were similar to popular non-artemisinin therapies in the for-profit sector, and QAACT market share in the for-profit sector was also high in both urban and rural areas (over 60%) (Tougher et al., 2012). Together, this could imply that the distribution of AMFm-subsidized QAACTs would be relatively equitable in Kenya, and perhaps even follow the pattern of unsubsidized delivery in the for-profit sector in Uganda and Nigeria. However, the likely equity of AMFm in other countries is unclear, as no other country achieved both market share of QAACTs in the for-profit sector of over 50% and prices of QAACTs equivalent to non-artemisinin therapies QAACTs.

Our paper is one of the few studies that examines the equity of public and private mechanisms for delivering health commodities, so our empirical results provide an important contribution to the literature. A notable exception is a multi-country study of alternative systems for delivering bed-nets, which similarly found that delivery through commercial markets was more equitable than delivery through the public health systems in most of the study countries. However, this study was conducted prior to large-scale public sector distribution of nets, so these results are dated (Webster et al., 2005). Indeed, more recent studies from Tanzania and Kenya found that public sector distribution was more equitable than distribution through the for-profit sector (Khatib et al., 2008; Noor et al., 2007).

6.2 | Methodological contributions and limitations

To our knowledge, this is the first study to carefully consider the possible approaches for valuing public subsidies delivered in the for-profit sector for the purpose of an equity analysis, and to examine the advantages and disadvantages of the possible alternatives. We argue that a price-gap approach, which is rooted in economic theory on the operation of subsidies, provides the most comprehensive valuation. Although our focus was on subsidies for public health products, the analysis of the advantages and disadvantages is also applicable to programs that subsidize health services in the for-profit sector.

Applying the price-gap approach to AMFm highlighted three methodological challenges. The first issue was calculating the counterfactual price for AMFm-subsidized medicines. We used a simple approach for imputing the value of a QAACT purchased in the for-profit sector, which is similar to what is done when valuing services for most public sector BIAs (Wagstaff, 2012). Although it would have been preferable to have experimental or quasi-experimental evidence to compute the counterfactual price, these data were not available for AMFm. Should such data be available, our price-gap approach could incorporate them, including allowing for heterogeneous counterfactual prices for households with dif-

ferent characteristics. Although our imputed counterfactual price may have differed from the actual counterfactual price, the overall findings that AMFm was more pro-poor in Uganda in the BIA compared to the utilization-based equity analysis would be unchanged assuming the actual counterfactual price was constant[7] (Wagstaff, 2012).

The second challenge was identifying which products purchased from the for-profit sector were subsidized through AMFm. Although the ACTwatch surveys collected data on the presence of the AMFm logo, logo information was often missing. We addressed this problem by making simplifying assumptions about which products were subsidized, and examining the robustness of our results to these assumptions. It should be noted that this challenge was not limited to the BIA; the utilization-based analysis also required determining whether or not antimalarials bought in the for-profit sector were subsidized. Evaluations of other subsidy interventions may not need to contend with this issue, as, for example, many commodity social marketing programs involve distinctive branding. Had over-branding been used on AMFm, distinguishing between subsidized and unsubsidized antimalarials may have been easier.

The high volume of missing drug expenditure data was the third challenge, which is a common issue in household surveys which collect medicine prices (Rockers et al., 2019). Very few studies involving equity analyses have directly addressed missing data in a health variable, and those that have relied on using multiple imputation with an MAR assumption (Zhong, 2010; Bilger et al., 2017). Although MAR is more realistic than the MCAR assumption, it cannot be confirmed based on observed data. The MAR assumption may be plausible in our setting, as either antimalarial cost or total treatment cost was reported for over 85% of antimalarials obtained from for-profit source. Therefore, including total treatment cost along with socioeconomic position and other household characteristics in the imputation model may have been sufficient to justify the MAR assumption (Sterne et al., 2009). Nevertheless, our novel extension of the partial identification approach to the concentration index is a substantive methodological advancement. The perceived difficulty of performing estimation under an MNAR mechanism has led researchers to use the MAR assumption by default (Zhong, 2010). The partial identification approach requires no assumptions, so is compatible with MNAR mechanisms (Manski, 2005).[8] Future work could extend the procedure used in this paper to compute bounds in situations where the rank and health variables both have missing data.

An advantage of the multiple imputation and partial identification approaches is that they can both incorporate supplementary information to improve the analysis of missing data. One of the reasons that the level of missing price data was so high was that some households only knew the total cost of treatment at the source they visited, rather than the cost of the antimalarial drug they purchased. Total treatment cost was reported for approximately 80% of the QAACTs purchased in the for-profit sector that were missing drug prices in Uganda. Households may have an easier time recalling the total cost of treatment at an outlet, either because they were not provided an itemized account of their purchase or because total treatment cost is more salient to the respondent. We were able to incorporate total treatment cost data in the imputation model and use it to narrow down the bounds in the partial identification analysis.

Identifying children with the same need for malaria treatment was another methodological challenge addressed in this paper. Previous studies have examined the equity of ACT use among all febrile children (Galactionova et al., 2017; Khatib et al., 2013). We built on this approach by limiting the analysis to children that either had a positive malaria parasitological test, or fever but no test. However, in the context of limited diagnostic testing, it is likely that many of these children did not actually have malaria and hence did not need an antimalarial. Households may have additional information on the likelihood that their child's fever is caused by malaria. The pro-poor distribution of QAACTs from public and private sources in Uganda may be because wealthier households are less likely to suspect that their child's fever is caused by malaria, which would explain why receiving any form of malaria case management was lowest in the richest quintile. For example, richer households may live in areas with lower malaria incidence or live in higher quality housing, which could affect their perceptions of malaria risk. This is illustrated in Uganda, where bed-net ownership is similar across quintiles, but bed-net use is 8.5 percentage points higher among the poorest quintile compared to the richest (Galactionova et al., 2017). Nevertheless, the approach used in our paper incorporates socioeconomic position-related differences in testing and testing outcomes. The results for public and private sector QAACT use in Uganda are less pro-poor than they would have been had we used the traditional approach of including all febrile children, because testing and receiving a negative result was higher among wealthier households. As rates of parasitological testing of fever increase, our definition of suspected malaria would more closely approximate children who need an antimalarial.

Our study had several other limitations. We present evidence from single cross-sectional surveys within two of the countries that implemented AMFm. These surveys were undertaken after the Global Fund started rationing orders for the for-profit sector, so may not be indicative of equity at an earlier stage of the intervention. The surveys also only focused on children under five that recently had a fever, which is typical for household surveys related to malaria prevention and treatment as young children are particularly vulnerable to malaria. The results may not be indicative of the overall

private sector component of the intervention, because QAACTs for all ages were subsidized through AMFm. Moreover, our analysis did not address other important aspects of access to high-quality malaria case management, such as whether providers from different sectors were more likely to provide parasitological diagnosis or dispense the full treatment course for the child's weight.

7 | CONCLUSION

The common assumption that public sector delivery is more pro-poor than delivery through the subsidized and unsubsidized for-profit sector may be unfounded in some contexts. Empirical investigation is required to understand which distribution mechanisms serve which households. In the case of AMFm, the use of subsidized distribution through both public and for-profit sectors was concentrated among the better-off in Nigeria, but among the poor in Uganda. Unsubsidized private provision was distributed equally across wealth quintiles in both countries. Private sector subsidies may have a role in bolstering access to effective malaria treatments, including among the poor, but equity needs to be monitored carefully in specific contexts.

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CONFLICT OF INTEREST

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ETHICAL APPROVAL

Ethics approval for the independent evaluation of AMFm was obtained by the institutional review boards of the London School of Hygiene & Tropical Medicine and ICF International, and the household survey protocols received ethical approval from the National Health Research Ethics of Nigeria (NHREC) and the ethical approval committee at the Ministry of Health of Uganda.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from Population Services International. Restrictions apply to the availability of these data, which were used under license for this study. Data may be available upon request from https://urldefense.com/v3/__http://www.actwatch.info__;!!N11eV2iwtfs!41KuzERnDUSpguswgBkeC7tRXekO1AP-bAktVOIL3-lhVywGFb0smL4Vkl9LLxXQ4$with the permission of Population Services International.

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ENDNOTES

[1] Malaria is suspected clinically based on the presence of fever. As fever may have other causes, diagnosis based solely on clinical symptoms results in overtreatment (WHO, 2015).

[2] Examining the equity of out of pocket payments is useful for understanding disparities in the financial burden on households for obtaining the product.

[3] AMFm-subsidized QAACTs had a green-leaf logo printed on the medicine's primary and secondary packaging. In cases where the medicine packaging was no longer available, caregivers were asked to recall whether the logo was present on the medicine's package. An alternative approach to identifying subsidized products would be to use the presence of this logo. However, the logo was relatively small compared to the manufacturers' own branding. In practice, a high proportion of respondents reported that they did not know whether the packaging had

the logo (20% in Nigeria and 24% in Uganda), and we have concerns about the reliability of caregiver recall about the presence of the logo in general, so have instead opted to assume that all private sector QAACTs were subsidized.

[4] Few children received a QAACT from both a public facility and a for-profit outlet. In Uganda, 23/796 children that received a QAACT from either a public or private source reported receiving a QAACT from both sources, and in Nigeria, no children received a QAACT from both a public and private outlet.

[5] Since use of subsidized QAACTs was correlated with the household's socioeconomic position, the complete case analysis would be biased in the direction of the correlation.

[6] Children with suspected malaria were febrile children that had a positive parasitological test or did not receive a test.

[7] In the context of public sector BIA, Wagstaff (2012) demonstrated that when the unit cost of a service (which is used to value health services in a public sector BIA) is constant, the concentration index of the subsidy is the weighted difference of the concentration index of utilization and the concentration index of user fees, and weights are a function of unit costs. Consequently, other things being equal, the concentration index of the subsidy decreases (i.e., becomes more pro-poor) the more concentrated fees are among the rich.

[8] Although our solution was designed for situations where the missing data problem is in the health variable alone, this is likely to be applicable to many datasets from low- and- middle-income country settings where asset indices are ubiquitously used to measure socioeconomic position. Asset indices typically have very high levels of reporting, because the required information is based on interviewer observation (e.g., materials of roof) and questions that are easy and quick for respondents to answer (O'Donnell et al., 2008). Moreover, standard practices in constructing the Demographic and Health survey (DHS) Wealth Index, such as re-coding "don';t know" response to "no," ensure that the index is typically fully observed (Rutstein, 2015), albeit potentially measured with error.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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