THE DECADE OF VACCINE ECONOMICS PROJECT

This study is part of a collaborative effort between the International Vaccine Access Center (IVAC) at Johns Hopkins University, Makerere University School of Public Health (MakSPH) and the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b). We would like to acknowledge the contribution of Hwajung (Jenny) Lee (MPH/MBA 2019’) to the discussion on productivity loss in this report. We would also like to thank Lesong Conteh, Ulla Griffiths, Solomon Memirie and Logan Brenzel for their invaluable feedback on the methods and the analysis.

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**Uganda**

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Acronyms

Institutions
BMGF  Bill & Melinda Gates Foundation
icddr,b  International Centre for Diarrhoeal Disease Research, Bangladesh*
IVAC  International Vaccine Access Center
JHU  Johns Hopkins University
MakSPH  Makerere University School of Public Health
UNCST  Uganda National Council for Science and Technology

Projects
DOVE  Decade Of Vaccine Economics
COI-FS  Cost Of Illness Field Study (project part of DOVE IV)
COI-SR  Cost Of Illness Systematic Review (project part of DOVE IV)

Management
FRO  Field Research Officer (field study coordinator):
  Sayem Ahmed and Md. Wazed Ali in Bangladesh
  Anthony Ssebagereka and Gatien de Broucker in Uganda
FRA  Field Research Assistant (data collector)
AG  (DOVE) Advisory Group
  Ulla Griffiths, Lesong Conteh and Solomon Memirie
IRB  Institutional Review Board

Public health
COI  Cost Of Illness
LMIC  Low- and Middle-Income Countries
PFP  Private For-Profit healthcare facility
PNFP  Private Not-For-Profit healthcare facility

Surveys & tools
DHOS  District Health Office Survey
HFFS  Healthcare Facility Follow-up Survey
HFMS  Healthcare Facility Main Survey
PCES  Patient Caregiver Exit Survey
PCFS  Patient Caregiver Follow-up Survey
PDS  Pharmacy and Drug shop Survey

* The acronym “icddr,b” is written in lower case characters.
Background

Immunization-preventable diseases such as pneumonia, diarrhea and measles are among the main contributors to child morbidity and mortality in low- and middle-income countries (LMIC). In addition to health impacts, these diseases also lead to economic losses through increased use of healthcare resources and loss in productivity. While vaccines are widely regarded as one of the most cost-effective public health interventions, gaps exist in the evidence base on their broader economic impact, including the costs of illness averted due to vaccination in LMIC. The existing literature focuses largely on public sector costs, often in tertiary and secondary level facilities, with a lack of data on costs for medications, diagnostics, rehabilitation and transportation, and may not capture the impact on households’ economic circumstances. The studies reviewed thus far indicate large variations in cost estimates for diseases like measles, pneumonia, and diarrhea within and across countries. These variations may be due to differences in disease classifications, definition of cost categories, sampled populations, data sources, discount rates, and other factors.

As a growing number of countries face graduation from donor support, there is a going need to better understand the true economic burden of disease combined with traditional burden of disease estimates. Cost studies provide data on disease impact to guide public health policy decisions and evidence-based interventions for addressing effectively public health threats. IVAC partnered with the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) and Makerere University School of Public Health (MAKSPH) to estimate the costs of treatment and productivity loss of three childhood diseases – pneumonia, diarrhea, and measles – in Bangladesh and Uganda.

Study objectives

1. Estimate the cost of treatment and productivity losses for pneumonia, diarrhea and measles by socio-economic status and location of care to understand their economic impact.

2. Examine the distribution of the burden by household socio-economic status, immunization status, gender and residence.

Project phases

The DOVE COI-FS project takes place in 3 phases: data collection, pre-analysis and follow-up, and analysis.

Phase I: Data collection

Data collection took place from July 2017 to April 2018 in Bangladesh in Sylhet and Rajshahi divisions, in an urban and a rural district in each division: Sylhet City Corporation and Maulvibazar district for Sylhet division, and Rajshahi City Corporation and Natore district for Rajshahi division. In Uganda, data collection took place from August 2017 to July 2018 in one district per region: Gulu district in the Northern Region, Jinja in the Eastern Region, Mbarara in the Western Region and Wakiso in the Central Region. The identification of a hospitalized disease case used the diagnosis at discharge – 2nd diagnostic as recommended 1 – based on clinical assessment with or without laboratory confirmation. Outpatient cases used the diagnosis provided during triage, based on clinical assessment.
We interviewed administrators and managers of the healthcare facilities to obtain cost data, and medical staff, laboratory technicians, statisticians and storekeepers for data on utilization from the healthcare perspective. Whenever possible, we used administrative data and reports to support and adjust the recorded estimates. For tertiary and secondary level hospitals, data collection was restricted to the pediatric ward. Healthcare facility costs included facility, its operating costs, i.e. overhead costs and staff salaries, and itemized costs for the instruments, furniture, supplies and medications used for diagnostic tests, hospitalization and treatment. Among those costs, we considered as capital costs the medical equipment, vehicles and furniture used to care for pneumonia, diarrhea or measles cases. A one-time healthcare facility survey collected itemized costs and average time spent by different healthcare professionals. A monthly facility survey captured the overhead costs from annual expenses and utilization rates for supplies and medications from inventories. We collected additional data on medication pricing in the private sector in pharmacies. The pharmacy owner or pharmacist in charge was interviewed.

Caregivers were interviewed at the time of discharge from the facility and 7 to 14 days later over the phone, effectively capturing all costs incurred at the facility where the interview took place, in previous facilities, and after discharge. We asked about the out-of-pocket payment made during the episode of illness, prompting them about direct medical costs (registration fees, medications, medical procedures, hospitalization) and non-medical costs (transportation to and from the facilities, meals and lodging for the caregiver). To estimate their indirect cost, we also asked about the time they spent providing care for the child at the facility and at home. Additionally, we collected information about their household, their daily expenditures and their income to assess their socio-economic status. Progress tracking and data quality checks are described in the next section.
Phase II: Pre-analysis and follow-up

Pre-analysis includes the processing necessary to standardize the survey results beyond data collection with formatting, cleaning, progress tracking and follow-up. Any issue picked up during and after data collection was reviewed by all teams and follow-up with the selected healthcare facilities and other institutions was performed whenever necessary. These activities are reported in the section titled Data quality control.

First, datasets are set up and formatted for easier reading and manipulation by the different teams. This process includes renaming variables, assigning labels, formatting dates and numbers. Then, datasets are cleaned and any error is corrected. Corrected errors included misspelling (for “other” or open-ended questions), incorrect date and time, missing data, incorrect values.

For Bangladesh, icddr,b reviewed the data prior to submission to the central server. They tabulated selected variables to check consistency and any missing information to clean the datasets. They maintained a spreadsheet on the findings during cleaning process.

For Uganda, MAKSPH and JHU used MS Excel to perform formatting and data cleaning. A standard protocol for dataset formatting and cleaning was developed in December 2017: Monitoring study progress and data quality. In summary, the coordinators set up VBA macros to format and identify potential inconsistencies in the datasets. MAKSPH coordinator regularly examined the datasets and let the JHU coordinator know about any correction so the JHU coordinator may update the VBA macros. To assess the study progress, we generated pivot tables and graphs from the clean dataset to provide information on the status of data collection at the time the dataset was downloaded from the cloud.

Any inconsistency or missing information in the dataset identified during cleaning process were recollected from field sites (healthcare facilities, district health offices and pharmacies) during data collection and after it was completed.

Phase III: Analysis

The analysis took place in two stages: descriptive and in-depth.

Descriptive cost of illness analysis: the datasets were examined in a standardized manner, applied by all teams for both countries, to generate equivalent and comparable cost of illness estimates. We calculated the average costs per episode of illness by disease severity (length of stay), age, district, and household wealth. This stage in the analysis required ongoing inter-team coordination to produce the best standardized method and use the latest evidence.

In-depth cost of illness analysis: We also estimate the proportion of households facing catastrophic health spending and medical impoverishment from pneumonia, diarrhea and measles. Catastrophic thresholds are based on food expenditure ratios of poorer to wealthiest quintiles and are used to estimate the impact on poorer households with fewer resources to cope. Sample-based quintiles are compared to population-based wealth quintiles. Impoverishment impact is estimated using country and regional poverty lines. Additionally, we performed a benefit-incidence analysis, using the reported income data.
**Costing approach**

The study was designed as an incidence-based study with an ingredient-based approach. We used an incidence-based approach to capture a full episode of disease, collecting cost and utilization data from the start of the episode to its end or up to the follow-up interview (whichever came first)\(^1\). We identified individual resources used in the treatment of pneumonia, diarrhea and measles for each healthcare facility (reported as “typically provided”) and for each patient, and asked about the cost, the utilization and, when relevant, the price charged to patients. We also captured aggregated estimates for each type of cost and category of expenses from the patient caregiver perspective: such costs could include non-resource-related costs such as a registration fee.

In our data collection, we defined costs as:

- **Resources purchased once and used for many patients were shared capital costs.**
- **Resources purchased recurrently and used for many patients were shared recurrent costs.**
- **Resources purchased recurrently and used for no more than one patient were itemized recurrent costs.**

<table>
<thead>
<tr>
<th>Resources Purchased</th>
<th>Once</th>
<th>Recurrently</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used for 1 patient (non-shared)</td>
<td>N/A</td>
<td>Itemized recurrent costs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medical supplies (gloves)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medications</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transportation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Food</td>
</tr>
<tr>
<td>&gt; 1 patient (shared)</td>
<td>Shared capital costs</td>
<td>Shared recurrent costs</td>
</tr>
<tr>
<td></td>
<td>Medical equipment (X-ray)</td>
<td>Overhead costs (electricity)</td>
</tr>
<tr>
<td></td>
<td>Furniture (bed, chairs, sheets)</td>
<td>Medical staff costs</td>
</tr>
</tbody>
</table>

Data collectors could either report how many patients / how long does this resource serve (measuring lifetime for capital costs) or what quantity of this resource is used per patient (measuring utilization rate for itemized recurrent cost). For shared recurrent costs (overhead and staff costs), data collectors asked how much of this resource was purchased for the period of data collection.

In the analysis, we allocated the costs reported by the caregiver into types of costs including:

- **Direct medical costs**: medications, investigation costs, registration fees, hospitalization fees.
- **Direct non-medical costs**: transportation to and from the facilities, meals while seeking care.
- **Indirect costs**: income loss related to the episode of illness.

To group and compare costs, we grouped medical resources used for under 5 healthcare services: diagnostic, on-site treatment covering all medical resources used while being treated at the facility (excluding bed and costs related to accommodations during hospitalization), accommodations including resources related to the patient’s stay at the facility overnight (for inpatient cases only), treatment follow-up covering medical resources provided to the caregiver for post-visit treatment at home and death handling including all medical resources used to care for a deceased patient (excluding funeral and other non-medical costs).
**Ethical approvals**

**Johns Hopkins IRB approval**

The Institutional Review Board (IRB) of the Johns Hopkins Bloomberg School of Public Health examined the risks and benefits related to this research project and granted ethical approval (IRB #7256). An amendment was submitted and approved on December 14\(^{th}\), 2017 for the addition of the *District Health Office Survey* in Uganda.

**Country-based IRB approval**

The IRB of the International Diarrheal Disease Research Centre, Bangladesh examined the risks and benefits related to this research project in the context of Bangladesh and granted ethical approval on June 7\(^{th}\), 2017 (IRB PR-16067).

The IRBs of Makerere University and of the Uganda National Council for Science and Technology examined the risks and benefits related to this research project in the context of Uganda and granted ethical approval on May 12\(^{th}\) and 31\(^{st}\), 2017, respectively (IRB HS 2131). In Uganda, additional reviews by healthcare facility IRB also took place before allowing data collection to take place.

**Advisory group review**

On 26 April 2018, the DOVE advisory group (AG) met to review the status of the DOVE project. Extensive feedback was provided in response to the challenges identified and consensus was sought to prioritize the analysis towards specific results. Questions raised from the AG review and the study team's follow-up and response are reported in this report.

**Stakeholder feedback**

Specific results should be prioritized as preliminary results to help build the audience for the final dissemination work. The outputs of DOVE are valuable to international and local stakeholders, if developed and framed in a way that is useful for them. In Uganda, the work to identify stakeholders started with the study as part of our effort to access difficult data sources. In Bangladesh, no such work was undertaken. IVAC will provide a template to prepare the local teams for preliminary result generation and dissemination, and stakeholders’ engagement. Some of the major stakeholders for the project in Uganda include: health facility managers, District Health Officers and the Uganda Association for District Health Officers, Ministry of Health, researchers and academics from Makerere University, Immunization Technical Advisory Group, UNEPI, Uganda Immunization country evaluation group, Uganda Immunization technical working group, PATH, The Fifth Child Project, UNICEF, and WHO.
The data collection forms in the tablets provides specific checkpoints that allows to review the location, time and input of the data collectors. In the forms, the data collector will:

- Review the checklist for the data collection process (steps 2 – 6)
- Record date and time of start and end of survey (OS date & time) (step 3)
- Record GPS location at the start of the survey (OS GPS location) (step 3)
- Take pictures of HMIS forms as needed for data input (step 3)
- Take pictures of medications presented by the caregiver (step 3)
- Review the form with the FRO and mark it as “final” (step 4)

Throughout the data collection, the JHU team retrieved data (step 8 – 9) and reviewed the following checks for both performance evaluation and adjusting the cleaning procedures.

- Number of surveys completed per disease
- Start and end time for an interview (duration)
- GPS coordinates
- Data completeness and missing sections (coded as 89, 99 and blanks)

After data collection, the team used these checks to assess the integrity of the data and whether adjustments to the approach to cost of illness need to be made.

All healthcare facility survey forms and a sample for patient caregiver survey forms filled by FRA were reviewed by a FRO. Any challenges met during data collection was discussed for potential bias. If errors, inconsistencies or biases were found, the FRO and FRA decided to find additional data and apply corrections prior to finalizing and submitting the forms.

For healthcare facility surveys, the FRA (and, for larger issues, the FRO) would return to the facility to review the data and request additional information from alternative sources. For PCES, the FRA would have the questions from the PCES ready when proceeding with the follow-up and ask them before starting the PCFS.
Methods

Estimation of cost of illness from the healthcare perspective

For the healthcare facility perspective, all costs were patient-specific with exception for operating costs (overhead and salaries) and capital costs. Capital and non-capital items are separated based on the definition provided earlier. Where:

- $S$ is the total shared cost attributable to the disease,
- $I$ the total non-shared cost for the disease,
- $A$ the total annualized shared cost including shared capital and recurrent costs,
- $p$ the total number of patient-days (with $p_i$ the number of patient days for caregiver $i$),
- $c_{ij}$ the cost and $u_{ij}$ the utilization rate of non-capital item $j$,
- $n$ the total number of patients and $k$ the total number of items,
- $oh$ the total overhead cost and $u_{oh}$ its utilization rate,
- $sc$ the total staff cost and $u_{sc}$ its utilization rate,
- $B_j$ the annualized cost of infrastructures,
- $C_j$ the annualized cost of shared medical equipment and $u_j$ the utilization rate of shared capital item $j$, and
- $D_j$ the annualized cost of dedicated capital item $j$.

Average COI per episode = $\frac{S + I}{n} = \sum\limits_{i=0}^{n,k} \left( oh \times u_{oh} + sc \times u_{sc} + (B_j + C_j) \times u_j + D_j + c_{ij} \times u_{ij} \right) / n$

With the total shared cost attributable to the disease, which simplifies into an annualized shared cost ($A$) and a patient-days utilization rate ($p_i / p$). See explanation for shared costs.

$S = \sum\limits_{i=0}^{n,k} \left( oh \times u_{oh} + sc \times u_{sc} + (B_j + C_j) \times u_j + D_j \right) = \sum\limits_{i=0}^{n,k} \left( A \times \frac{p_i}{p} + D_j \right)$

And with the total non-shared cost for the disease.

$I = \sum\limits_{i=0}^{n,k} \left( c_{ij} \times u_{ij} \right)$
Shared costs

The equation below summarizes the shared costs attributable to each disease:

\[
Attributable \text{ shared costs} = S = \sum_{i=0}^{n,k} \left( oh \times u_{oh} + sc \times u_{sc} + (B_j + C_j) \times u_j + D_j \right)
\]

Initially, we planned to use the ratio of the room sizes dedicated to care for pneumonia, diarrhea and measles over the size of the facility to estimate \(u_{oh}\) and \(u_j\), and the ratio of time spent by each category of healthcare staff on each disease over the total time spent at the facility for \(u_{sc}\).

As the patient-days ratio based on HMIS data was applied for all three different shared costs, the formula for the attributable shared costs can be simplified into the following equation:

\[
S = \sum_{i=0}^{n} \left( oh + sc + B_j + C_j \right) \times d_i + D_j = \sum_{i=0}^{n} (A \times d_i) + D_j
\]

Overhead costs

Overhead costs were assessed monthly for the period of data collection: July 2017 to April 2018 in Bangladesh and July 2017 to June 2018 in Uganda. Since the full fiscal year in Bangladesh was not captured, we generated an average monthly overhead cost from the collected data (9 months) to estimate the cost for the whole year. In Uganda, we also generated an average monthly overhead cost to replace missing months.

To assess the share of overhead costs attributable to each disease, we looked at three different methods: room size, patient-days ratio based on the HFFS and patient-days ratio based on HMIS data. We chose to use a patient-days ratio rather than the room size data as these data were not usable for either country. Furthermore, we chose to use HMIS data as the source of our healthcare facility utilization data to estimate patient-days ratios as some of the facilities reported overhead costs for the whole facility (including adult patients) rather than for the pediatric ward only, and our utilization data do not include any information on adult utilization. For facilities that reported overhead costs for the whole facility, we used the total number of patients – adults and children – as denominator \(p\), while for those that reported them for the pediatric ward only, we used the total number of children who used the facility as denominator.

Therefore:

\[
\text{Total attributable overhead costs} = \sum_{i=0}^{n} \left( oh \times \frac{p_i}{p} \right)
\]

Labor costs

Labor costs were assessed once in the HFMS as an annual estimate for salary and fringe benefits. We excluded staff training from the calculation.

To assess the share of staff costs attributable to each disease, we originally considered the use of time allocation based on the ratio of the time spent by a medical staff on patients with pneumonia, diarrhea or measles over the time spent in the pediatric ward and overall at the healthcare facility. However, the lack of reliable data on time spent on each disease prohibits the use of this method. Similarly to overhead costs, we chose to use a patient-days ratio rather than the time allocation data and to use HMIS data to estimate patient-days ratios for the reasons mentioned above. In Uganda, since the staff data was provided for the pediatric ward only for Healthcare Centres III and IV and Referral Hospitals, we used the total number of children treated at the facility as the denominator \(p\). Healthcare Centres II did not have a distinct ward or staff dedicated to pediatric care: the total number of patients – adults and children – was used as the denominator \(p\).

Therefore:

\[
\text{Total attributable staff costs} = \sum_{i=0}^{n} \left( sc \times \frac{p_i}{p} \right)
\]
**Capital costs**

The cost of each medical equipment and furniture was annualized, using an annuity factor of 25.73 for infrastructure and 4.58 for medical equipment, based on a set lifetime of 50 years and 5 years, respectively, and a discount rate of 3%.

\[
B_j = b_j \times \frac{\text{size}_{\text{pedward}}}{(1 - (1 + 0.03)^{-50})} = b_j \times \frac{\text{size}_{\text{pedward}}}{25.73}
\]

\[
C_j = c_j \times \frac{1}{(1 - (1 + 0.03)^{-5})} = c_j \times \frac{1}{4.58}
\]

\[
D_j = d_j \times \frac{1}{(1 - (1 + 0.03)^{-5})} = d_j \times \frac{1}{4.58}
\]

There are two different utilization rates applied to capital costs. For the few facilities with a ward dedicated to pneumonia, diarrhea or measles treatment, the capital costs dedicated to the disease had a utilization rate of 1. Other capital costs were shared across all pediatric diseases with the same utilization rate as the overhead costs (patient-days). Infrastructure is always a shared capital cost \((B_j)\), while medical equipment can be shared \((C_j)\) or dedicated \((D_j)\).

Total dedicated capital costs \(= \sum_{j=0}^{k} (D_j \times 1)\)

Total shared capital costs \(= \sum_{i=0}^{n} \left( (B_j + C_j) \times \frac{p_i}{p} \right)\)

Thus, yielding the following total capital cost:

Total capital cost \(= S = \sum_{i=0}^{n} \left( (B_j + C_j) \times \frac{p_i}{p} + D_j \right)\)

Total capital cost per episode \(= \frac{S}{n} = \sum_{i=0}^{n} \left( (B_j + C_j) \times \frac{p_i}{p} + D_j \right) / n\)

**Non-shared costs**

The non-shared costs and utilization rate of medications and medical supplies were estimated for each patient.

Total non shared cost \(= l = \sum_{i=0}^{n} (c_{i,j} \times u_{i,j})\)

The unit cost \((c_{i,j})\) for disposable items and medications was specific to the healthcare service (diagnostic, on-site treatment, accommodations, treatment follow-up and death handling) provided at the facility caring for patient \(i\).

The utilization rate \((u_{i,j})\) for disposable items can be based on the average number of resources used per patient with the disease as estimated for each facility from the HFMS, except for the use of ventilators, oxygen and IV fluids that were reported by the patient caregiver in PCES and PCFS. We can also use the reported monthly consumption of these resources dedicated to the diseases for each facility, as measured in the HFFS. However, the consumption has been reported for all 3 diseases aggregated together.

The utilization rate \((u_{i,j})\) for medications should follow the reported use by patient caregivers as measured in PCES and PCFS and associated to each facility. The HFMS also provided an average number of medications used per patient with the disease as reported by the healthcare facility.
**Estimation of cost of illness from the caregiver perspective**

**Direct medical cost**

For each component of the direct medical costs, we had 3 groups: costs incurred at facilities before the current visit, at the current facility (where the PCES took place) and at facilities visited afterwards (and before the PCFS was performed). For each group, the costs were recorded for each facility visited, along with the facilities’ details.

\[ X \text{ is the cost of component } e \text{ (registration, investigations, medications, etc.) for patient } i \text{ and healthcare facility } j \text{ (visited before, currently or after) with } f \text{ the total number of facilities and } g \text{ of components.} \]

\[
\text{Total direct medical costs for patient } i = \sum_{i=0}^{n} \sum_{j=0}^{f} \sum_{e=0}^{g} (X_{i,j,e})
\]

For investigations and medications, there is the option in Uganda to use the reported cost of individual laboratory test and medication charged to patients by each facility as recorded in the HFMS as cost, and the reported use of tests and medications by each patient as recorded in the PCES and PCFS.

**Direct non-medical cost**

Transportation, food and other costs were reported in the same way as direct medical costs with \( Y \) as the cost of component \( e \) (registration, investigations, medications, etc.) for patient \( i \) and healthcare facility \( j \) (visited before, currently or after).

\[
\text{Total direct non medical costs for patient } i = \sum_{i=0}^{n} \sum_{j=0}^{f} (Y_{i,j,e})
\]

**Productivity loss**

In Bangladesh, the head of the household’s income is the only one reported. For this country, we used the head of the household’s average income as and the time spent getting to/from and in the healthcare system, and providing care at home. For Uganda, we recorded the income of all wage earners in the household, starting with the head of the household (see discussion on the valuation of productivity loss).

\[ Z \text{ is the average income per day associated with patient } i \text{ and } T \text{ is the time spent for patient } i \text{ at healthcare facility } j \text{ (visited before, currently or after) with } f \text{ the total number of facilities.} \]

\[
\text{Total direct medical costs for patient } i = \sum_{i=0}^{n} \sum_{j=0}^{f} (Z_{i} \times T_{i,j})
\]
**Estimation of cost of illness from the societal perspective**

The societal costs are the combination of the costs borne by the caregivers and the healthcare system using the following aggregation:

<table>
<thead>
<tr>
<th>Components</th>
<th>Calculation</th>
<th>Perspective¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct medical costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dedicated capital</td>
<td>▪ Add total cost of dedicated capital borne by facilities</td>
<td>G</td>
</tr>
<tr>
<td>Shared capital</td>
<td>▪ Add total cost of shared capital borne by facilities</td>
<td>G</td>
</tr>
<tr>
<td>Overhead</td>
<td>▪ Add total cost of overhead borne by facilities</td>
<td>G</td>
</tr>
<tr>
<td>Medical staff</td>
<td>▪ Add total cost of medical staff borne by facilities</td>
<td>G</td>
</tr>
<tr>
<td>Medical procedures (disposable items)</td>
<td>▪ Add total cost of medical procedures borne by facilities</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>▪ Add cost of investigations and hospitalization borne by caregivers from prior and follow-up care</td>
<td>H³</td>
</tr>
<tr>
<td></td>
<td>▪ Subtract cost of investigations and hospitalization borne by caregivers from the current visit</td>
<td>H³</td>
</tr>
<tr>
<td>Medications</td>
<td>▪ Add cost of medications borne by facilities</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>▪ Add cost of medications borne by caregivers in facilities</td>
<td>H³</td>
</tr>
<tr>
<td>Registration</td>
<td>▪ Add cost of registration borne by caregivers from prior and follow-up visits</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>▪ Subtract cost of registration borne by caregivers from the current visit</td>
<td>H³</td>
</tr>
<tr>
<td>Direct non-medical costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>▪ Add total cost of transportation borne by caregivers</td>
<td>H</td>
</tr>
<tr>
<td>Meals</td>
<td>▪ Add total cost of meals borne by caregivers</td>
<td>H</td>
</tr>
<tr>
<td>Other</td>
<td>▪ Add total other costs borne by caregivers</td>
<td>H</td>
</tr>
<tr>
<td>Indirect costs</td>
<td>▪ Add total indirect costs borne by caregivers</td>
<td>H</td>
</tr>
</tbody>
</table>

Notes: ¹ Perspective: G for Government and H for Households. ² Subtraction reduces the amount borne by the Government and transfers it to the Household perspective.

*We assumed that all costs borne by private healthcare were transferred to caregivers through charges and copayments.*
Estimation of disease burden indicators

Comparative analysis

We examined whether there were any differences in direct, indirect and overall costs for an episode of pneumonia, diarrhea or measles based on several subgroups (identified below) using an independent t-test or a one-way ANOVA and pair-wise test for variables with multiple groups. We tested whether the conditions to perform these tests were met with Shapiro-Wilk's test (normality) and Levene’s and Bartlett’s tests (equal variance). If the conditions were not met, we used the non-parametric Kruskal-Wallis rank test and a Wilcoxon pair-wise comparison.

For the household perspective, we reviewed the following parameters to elicit different cost of illness estimates:

- Month and season (as applicable) when care is sought
- Gender and age of patient (child)
- Gender and age of caregiver
- Education and income of the household head
- Types of service sought (inpatient/outpatient)
- District and distance of healthcare center from central regional location (district health office or main city)
- Residence of the patient (urban/rural)
- Reported household income
- Wealth index by assets
- Ownership of healthcare facility where care is sought
- Level of healthcare facility where care is sought
- Duration of hospitalization
- Number of health facility visits made
- Number and cost of previous visits
- Type and cost of medication
- Number and type of laboratory tests done
- Time lost off work or other occupations
- Insurance coverage

For the healthcare perspective, we reviewed the following parameters:

- Month and season (as applicable) when care is provided
- District and distance of healthcare center from central regional location (district health office or main city)
- Types of service provided (outpatient only/inpatient & outpatient both)
- Ownership and level of healthcare facility where care is provided
- Proportion of cases of the diseases of interest
- Different types of medications compared to guidelines
- Type of health worker cadre at the health facility

Catastrophic health expenditures

Catastrophic health expenditures were calculated using the share of direct cost (medical and non-medical combined) over the monthly income of the head of the household or the monthly household expenditures. The monthly expenditures comprised of food, clothing, supplies, leisure, tax paid, other healthcare expenses (not related to current episode) and other expenses. We determined that a household experiencing catastrophic health expenditures related to this episode of measles when they spent over 10% of their income, 10%/25% of their monthly expenditures or 40% of their monthly expenditures without food.

Principal Component Analysis

The socioeconomic status of each household was defined based on asset scores generated through a principle component analysis (PCA) approach. The PCA was based on the ownership of durable assets in the households, the households’ dwelling characteristics (e.g., wall, roof and floor materials, water and sanitation facilities, and utilities) and the possession of durable goods (e.g., radio and television). Based on their asset score ranking, the households were divided into five asset quintiles.
Data reliability and robustness

Healthcare facility data reliability

In both countries, data collectors found it challenging to obtain cost data from healthcare facilities. Facility managers were unable or unwilling to provide cost information for specific line items (e.g., cadre salary, logistics, utility bills). While the support for the MOH and its local offices allowed the teams to access most of the data in public facilities, private clinics and hospitals remained unwilling to share their financial information on the record with the research team. We engaged with them through learning modules and discussions on the purpose and outlook for this research work, which allowed the collection of the information to be done verbally with the facility managers. In such cases, the team could not triangulate the information provided verbally with receipts and administrative data.

Additionally, in Uganda, for questions on large monetary amounts (e.g., annual budget, overhead expenditures), several amounts were reported in ‘thousands’, thus missing three zeros. After revision with the data collectors, we revised the numbers to report everything in the same unit.

Healthcare capital costs

Medical equipment and furniture

In Bangladesh, unit price information of apparatus, logistics and equipment were not available in most of the healthcare facilities. Purchasing related information (e.g. unit price, purchasing year) for most of the capital items (e.g. chair, table, and medical equipment) was not available as the procurement is usually done at different levels of the ministry, so we collected this information from the central levels (CMSD, HED and CMMU). In case of unavailability of information, we collected market price. In Uganda, most of the information was available at the healthcare facility or at the district health office, depending on the district.

In both countries, several high-level healthcare facilities (hospitals) had permanent dedicated wards for pneumonia, diarrhea or measles. In such cases, data collectors would assume that the medical equipment and furniture allocated for these rooms are not shared with other pediatric services (but are shared across patients with the disease).

Despite extensive effort to assess the lifetime of the medical resource, it was not reported correctly: data appear incoherent and unreliable. Based on data collectors’ feedback, the respondents knew the original cost of the medical equipment and furniture but did not know how long or how many times they were used.

Buildings and infrastructure

In Bangladesh, using cost data from government records, we estimated that the cost of buildings was BDT 3,447 per square foot on average. In the absence of lifetime data, we would apply a set lifetime of 50 years and a discount rate of 3%, and estimate the cost of the infrastructure by level of healthcare facility.

In Uganda, the infrastructure costs were not recorded, nor estimated.

Healthcare recurrent costs

Overhead costs

For both countries, two estimates are available: last financial year (2016-2017) expenses as an annual estimate and current financial year (2017-2018) as monthly estimates.

In Uganda, overhead costs (electricity, water, telephone, maintenance, etc.) were reported for the whole facility (pediatric & non-pediatric) for most facilities. The collected utilization rates (though the HFFS) were only reported for all children visiting the pediatric ward and did not include patients using the non-pediatric ward. We are missing the total utilization rate including adults to disaggregate overhead costs and must use HMIS data to complement/replace it.

In Bangladesh, overhead costs were reported for the pediatric ward only for all facilities.
**Staff costs**

Healthcare facility managers reported the salaries and fringe benefits per category of cadre working in the pediatric ward on children with pneumonia, diarrhea and measles. Staff training and community outreach activities were reported by the healthcare facility managers (both countries) and district health officers (Uganda) but they were mostly related to preventive care (e.g., immunization campaigns) and not necessarily disease-specific (e.g., community health workers trainings).

**Item costs**

The cost for the facility and the utilization rate for medications and medical supplies that were not shared across patients were reported by the medical staff and healthcare facility managers for a typical case of each disease and by healthcare service provided (diagnostic, on-site treatment, accommodations, treatment follow-up and death handling).

**Healthcare utilization data**

**Staff time**

In Uganda, the time reported for the facility should be inclusive (thus larger) of the time reported for the pediatric ward and caring for pneumonia, diarrhea and measles patients:

\[
\text{Time spent in healthcare facility per week} < \text{Time spent providing services to children per week} < \text{Time spent providing services to children with pneumonia, diarrhea or measles per week}
\]

However, it was not always the case, hurting the reliability of reported staff time. In response, the team examined the use of time tracking forms, unfortunately those could not be systematically used to report staff time. From the feedback of the data collectors in both countries, the staff could not estimate the time spent on healthcare provided specifically to one of the three diseases, even as several facilities had a ward dedicated to one of the diseases. In both countries, the time spent at the facility and pediatric ward had typos. Some were easily identified and corrected, e.g., 40 days per week should be 40 hours per week, while others could not be corrected.

**Facility room size**

In both countries, generating data on room size was difficult. First, for larger facilities, rooms were rarely fully dedicated to treating pneumonia, diarrhea or measles (even when specifically called the disease’s ward), mainly due to overcrowding in inpatient services. It is also likely due to the seasonality of the diseases: as an example for Bangladesh, tents are installed outside of the icddr,b Dhaka hospital (not part of the DOVE study) during the monsoon season, if the number of severe diarrhea cases increase dramatically. Such procedures are, however, not systematic and cannot be assumed for every facility. For smaller facilities, rooms were never dedicated to a specific disease and, furthermore, not always dedicated to pediatric care.

Second, the most reliable source of room size data were the blueprints of the healthcare facilities, often held at a government office (district health offices in Uganda). These blueprints were readily available in Bangladesh, allowing us to estimate the size of the pediatric ward in each facility. They were not available in Uganda, leaving the data collectors to most often measure the rooms themselves with strings and pacing. When debriefed, the data collectors in Uganda would not recommend using the measurements they did as they could not easily measure the rooms occupied by patients.

**Discrepancy between reported cases and HMIS data**

We observed a discrepancy between the collected monthly utilization data (number of cases of pneumonia, diarrhea and measles) and the official HMIS data in Uganda. The monthly utilization data were collected from the administrative records at the selected healthcare facilities, obtained each following month (in August 2017 for July data).
The numbers of monthly pneumonia and diarrhea cases reported in the study were lower than those presented in the HMIS, with Gulu district exhibiting the strongest discrepancies. For measles cases, the trend is reversed for Jinja district where the number of cases reported in the study was higher than those presented in the HMIS. The following figures describes pneumonia, diarrhea and measles cases reported in field study sites and the national HMIS database for all districts in Uganda.

Pneumonia and Diarrhea Cases reported in the DOVE study and the HMIS data, Gulu district, Uganda. DOVE study (blue) vs. HMIS (orange) data for OPD pneumonia and diarrhea.
(Suspected) measles cases reported in the DOVE study and the HMIS data, Jinja district, Uganda. DOVE study (blue) vs. HMIS (orange) data for OPD measles.

MAKSPH and IVAC teams examined what may have caused such discrepancy in reporting. After investigating in all four districts and discussing with the local stakeholders involved (district health officers and healthcare facility managers), we found that a potential cause was the case definition used for the study: the disease alone without comorbidities (including HIV). Other causes, like adjustments made to the data at the district or national levels, were not excluded. The MAKSPH team is interested to conduct further investigations and in-depth analysis to provide an assessment of the healthcare performance.

Such tracking was not performed in Bangladesh. Disease specific statistics (pneumonia, diarrhea and measles) were not available to the study team during data collection. Total number of child treated/ lab test done/radiology were available but not specifically mentioned for diarrhea, pneumonia and measles.
**Patient caregiver data reliability and potential bias**

**Caregiver recruitment**

We reported in April 2018 to the AG that we may not reach the desired sample size in Wakiso district for reasons including higher rate of people who refused to participate to the study and several facilities did not help the study team identify cases. Wakiso district surrounds the capital city, Kampala, and has over 90% of Uganda’s private for-profit healthcare facilities. The AG suggested that this may hinder the representativeness of the data by lacking (1) caregivers from the most densely populated district, (2) caregivers from a higher income household and (3) caregivers using private for-profit healthcare facilities.

In response, the MAKSPH and JHU teams changed the selection of facilities and the expected sample size for each one of them to better allocate the data collectors’ effort and time. Official ID badges were made for each data collectors and healthcare facility managers were engaged with the DOVE newsletter dedicated to report the study progress in Uganda. As a result, the team reached the targeted number of caregivers for Wakiso, although spent less time in private for-profit facilities. The private sector may be underrepresented in the sample.

<table>
<thead>
<tr>
<th>Location</th>
<th>PCES</th>
<th>PCFS</th>
<th>Retention</th>
<th>PCFS timing: within 7 – 14 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>1985</td>
<td>1858</td>
<td>94 %</td>
<td>-</td>
</tr>
<tr>
<td>Rajshahi</td>
<td>946</td>
<td>886</td>
<td>94 %</td>
<td>-</td>
</tr>
<tr>
<td>Sylhet</td>
<td>1039</td>
<td>972</td>
<td>94 %</td>
<td>-</td>
</tr>
<tr>
<td>Uganda</td>
<td>1713</td>
<td>1459</td>
<td>85 %</td>
<td>1042</td>
</tr>
<tr>
<td>Gulu</td>
<td>386</td>
<td>264</td>
<td>68 %</td>
<td>161</td>
</tr>
<tr>
<td>Jinja</td>
<td>428</td>
<td>384</td>
<td>89 %</td>
<td>235</td>
</tr>
<tr>
<td>Mbarara</td>
<td>438</td>
<td>398</td>
<td>91 %</td>
<td>345</td>
</tr>
<tr>
<td>Wakiso</td>
<td>457</td>
<td>413</td>
<td>90 %</td>
<td>301</td>
</tr>
</tbody>
</table>

**Caregiver follow-up**

*Delay between PCES and PCFS in Uganda.*

<table>
<thead>
<tr>
<th>Outside PCFS timing</th>
<th>Average</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 7 days (performed early)</td>
<td>-2.3</td>
<td>-1.8</td>
<td>-6.0</td>
<td>0.0</td>
</tr>
<tr>
<td>After 14 days (performed late)</td>
<td>9.9</td>
<td>5.8</td>
<td>0.0</td>
<td>90.3</td>
</tr>
</tbody>
</table>

Note that these numbers are based on the date and time the PCES was started and ended, and on the date and time the PCFS was started. These data ongoingly informed the coordinators of the performance of the data collectors and allowed for appropriate discussions and training.

The PCFS could only be completed by phone and by the caregiver who originally provided consent and responded to the PCES. This condition has led data collectors to call the caregivers within the prescribed timeframe, but finally being able to reach the caregiver and perform the PCFS after 14 days have passed. In Uganda, Gulu district, data collectors reported that cellphone service coverage was poor, making it more difficult to reach caregivers. In Uganda, Jinja district, cellphone service coverage is good although data collectors also reported difficulties in reaching the caregiver who provided consent for follow-up. In Bangladesh, there were also reports of challenges reaching caregivers by phone. Later in the study period, additional effort was allocated to call caregivers and perform the PCFS, even beyond the prescribed timeframe. There is a risk of reporting bias for which we have limited control over a phone interview.

Additionally, we should note that the operating system of several tablets malfunctioned and provided an incorrect date and time as input for the surveys’ metadata. For instance, some observations have a start and end date corresponding to 1922 instead of 2017-18. In Gulu, some data collectors continued using older versions of the data collection form until mid-November 2017. The data was captured but the software did not correctly aggregate it with the data coming from the updated forms.
Collected data

Direct costs

For both countries, we asked caregivers to enumerate every healthcare facility (including alternative care like traditional healers) they visited for their child’s episode of illness, separating them into (1) the current facility where PCES took place, (2) facilities visited before the current facility and (3) facilities visited after the PCES and before the PCFS were performed. In Bangladesh, up to 3 facilities visited before the current facility could be included. Caregivers were asked to provide several details about the facilities they visited, including the name, the ownership (public/private) and the level.

For each facility identified, the caregiver was asked about the costs incurred for registration or consultation, laboratory tests and medical investigations, medications, accommodation (if hospitalized), meals and food, other costs, and in total. Transportation costs were also asked for each facility in Uganda. Due to challenges in recalling the information found during the pilot phase, caregivers were asked for the total transportation costs for all facilities visited before the current one in Bangladesh.

Additionally, in Uganda, the selected healthcare facilities were asked about the fees charged to patients / caregivers for using specific resources and medications.

Utilization rates

Detailed time spent by service (waiting room, outpatient area, pediatric ward / inpatient bed, emergency room, and intensive care unit) was recorded for the current facility and facilities visited afterwards for both countries, and in facilities before the current visit in Uganda.

For both countries, caregivers were asked about each and every medication used during this episode of illness for all facilities visited. We recorded the generic name, the route, the prescribed dose and duration and where it was purchased. In Uganda, whenever possible, the data collector offered to take a picture of the medication prescription and fill in the details later on. This allowed the study coordinators to thoroughly review the data and correct any mistakes made by the data collector during the pre-analysis phase.

For both countries, caregivers shared, to the best of their knowledge, which and how many laboratory tests were performed overall, including: Chest X-rays, sputum tests, blood tests, stool cultures and other tests (lumbar puncture, cerebrospinal fluid analysis, etc.). Based on the feedback of healthcare facility managers and health professionals during the pilot phase, we asked caregivers about these tests overall rather than for each facility. At the current facility, the caregiver could review their medical record to find this information.

Household expenditures

Caregivers were asked about the household’s consumption and expenditures. It included expenses on food, rent, other children’s healthcare, clothes, hygiene products, household items, leisure and taxes. Most expenses were asked for the last 30 days, apart for food: asked for the last 7 days due to severe recall bias found during the pilot phase. If the household grew its own crops and food, the data collectors asked the caregiver to estimate the market value of their production. We also asked whether the household received help in-kind and, if so, the approximate value of this contribution.

Productivity loss

Time loss

Time loss was captured for all facilities visited for this episode of illness, including time loss by service (emergency room, waiting room, etc.) for the facility where the PCES took place. Caregivers were asked how much extra time they had to spend on the sick child on top of regular childcare to estimate the time spent at home and dedicated to care. Time loss for the head of the household was not recorded. The time spent on transportation was also included in the estimated time loss, with exception to the time loss in transportation to facilities before the current visit in Bangladesh as it was not collected.

Caregivers were also asked about their occupation (if they were wage-earners) and about the type of activity they had to forgo due to healthcare, from work to a range of non-remunerated activities. We assumed a workday of 8 hours.
Time valuation

In Bangladesh, during the pilot phase of the data collection in response to the challenges posed by questions around caregiver’s income, the local stakeholders and partners recommended that the questions focus on the head of the household’s income as a proxy for the whole household’s income. The caregiver surveyed could be the head of the household, but not necessarily. Thus, the only possible valuation for productivity loss in Bangladesh is the head of the household’s income.

In Uganda, the data collectors were able to ask about every wage-earner in the household without any limit in numbers, starting with the head of the household. If the caregiver was a wage-earner, their salary was captured. Income could be reported in different time units to accommodate all occupations, including seasonal work.

During the dissemination seminars in October and December 2018, local stakeholders asked whether we could use the head of household’s income as valuation for productivity loss rather than the caregiver as it may systematically underestimate the cost of the loss of time and associate this lower cost to the fact that women were often the caregiver and their husband the head of the household and main wage-earner. They suggested that time loss should be presented without any type of valuation to let them attribute a value to the time loss.

**Pharmacy and drug shop data reliability**

For the pharmacy and drug shop survey, pharmacies attached to the selected healthcare facilities do overlap each other. We asked the AG about how it may affect the COI estimates, whether we should review the selection and assign weights. The AG shared that they would follow healthcare facility staff and health officers’ recommendation on the selection of pharmacies and drug shops.

In Bangladesh, 20 pharmacies and drug shops were included. Considering the small sample size, their reported costs and utilization data are not representative. Additionally, the pharmacies do not keep records of patients to whom they sold medications and, as a result, it was difficult to get specific number of patients who purchased the medication from there in the last month.

In Uganda, 282 registered pharmacies were included. Non-registered pharmacies and drug shops were excluded from data collection based on the request from the District Health Officers.

**Sample characteristics**

**Healthcare facility ownership**

In Bangladesh, few cases were captured in private not-for-profit healthcare facilities. The icddr,b team originally suggested to merge the observations from this sector with the private for-profit sector. However, we opted to keep them separate. Lower representation from the private not-for-profit facilities was likely driven by the sampling choice and effort allocation from the study team and may misrepresent the utilization rate by sector.

In Uganda, while fewer cases were captured in private for-profit healthcare facilities, the overall balance could adequately represent the utilization rate by sector. Districts with key not-for-profit hospitals drove up the study sample size for this sector, adequately representing divergent utilization rates across districts.

<table>
<thead>
<tr>
<th>Healthcare facility ownership</th>
<th>Pneumonia</th>
<th>Diarrhea</th>
<th>Measles</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bangladesh</strong></td>
<td>963</td>
<td>942</td>
<td>100</td>
<td>1985</td>
</tr>
<tr>
<td>Government</td>
<td>614</td>
<td>581</td>
<td>78</td>
<td>1273</td>
</tr>
<tr>
<td>Private for-profit</td>
<td>320</td>
<td>359</td>
<td>22</td>
<td>701</td>
</tr>
<tr>
<td>Private not-for-profit / NGO</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td><strong>Uganda</strong></td>
<td>725</td>
<td>829</td>
<td>159</td>
<td>1713</td>
</tr>
<tr>
<td>Government</td>
<td>380</td>
<td>456</td>
<td>105</td>
<td>941</td>
</tr>
<tr>
<td>Private for-profit</td>
<td>57</td>
<td>89</td>
<td>12</td>
<td>158</td>
</tr>
<tr>
<td>Private not-for-profit / NGO</td>
<td>288</td>
<td>284</td>
<td>42</td>
<td>614</td>
</tr>
</tbody>
</table>
Since both COI estimates and who bears its burden differ across sectors, annual country COI estimates should integrate the utilization rate by sector for the whole population. To stay coherent across the two countries, we chose to estimate the utilization rate by sector from each country’s HMIS data.

Patient caregivers

For Bangladesh, we chose to only include caregivers who completed both the PCES and the PCFS to ensure that a complete episode of illness was captured. This implied a slight reduction of observations. For Uganda, we chose to include caregivers who completed the PCES even if they did not complete the PCFS, as it would change dramatically the representativeness of the different regions, particularly from Gulu district in the Northern region of Uganda.

In Uganda, 36% of PCFS were performed outside of the planned timeline (between 7 and 14 days) with an average of 2 days too early or 10 days too late. Excluding observations for which PCFS was not performed within the timeline would severely affect representation from Gulu district, we chose to include caregivers for whom the PCFS was performed outside of the time frame.
RESOURCES

Study documentation, survey tools, datasets and analysis programs are available online:

DOVE Study documentation

Datasets & tools for Bangladesh

Datasets & tools for Uganda

REFERENCES