Modelling costs of community-based HIV self-testing programmes in Southern Africa at scale: an econometric cost function analysis across five countries

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ABSTRACT

Background Following success demonstrated with the HIV Self-Testing Africa Initiative, HIV self-testing (HIVST) is being added to national HIV testing strategies in Southern Africa. An analysis of the costs of scaling up HIVST is needed to inform national plans, but there is a dearth of evidence on methods for forecasting costs at scale from pilot projects. Econometric cost functions (ECFs) apply statistical inference to predict costs; however, we often do not have the luxury of collecting large amounts of location-specific data. We fit an ECF to identify key drivers of costs, then use a simpler model to guide cost projections at scale.

Methods We estimated the full economic costs of community-based HIVST distribution in 92 locales across Malawi, Zambia, Zimbabwe, South Africa and Lesotho between June 2016 and June 2019. We fitted a cost function with determinants related to scale, locales organisational and environmental characteristics, target populations, and per capita Growth Domestic Product (GDP). We used models differing in data intensity to predict costs at scale. We compared predicted estimates with scale-up costs in Lesotho observed over a 2-year period.

Results The scale of distribution, type of community-based intervention, percentage of kits distributed to men, distance from implementer’s warehouse and per capita GDP predicted average costs per HIVST kit distributed. Our model simplification approach showed that a parsimonious model could predict costs without losing accuracy. Overall, ECF showed a good predictive capacity, that is, forecast costs were close to observed costs. However, at larger scale, variations of programme efficiency over time (number of kits distributed per agent monthly) could potentially influence cost predictions.

Discussion Our empirical cost function can inform community-based HIVST scale-up in Southern African countries. Our findings suggest that a parsimonious ECF can be used to forecast costs at scale in the context of financial planning and budgeting.

WHAT IS ALREADY KNOWN

⇒ Following success demonstrated with the HIV Self-Testing Africa Initiative, HIV self-testing is being added to national HIV testing strategies in Southern Africa.

⇒ Community-based models delivering HIV self-testing either at people’s homes or within the community setting with mobile outreach are a convenient approach for reaching undertested groups such as young people (16–25 years old) and men.

⇒ There is little guidance or empirical evidence on methods for forecasting costs at scale for programming and planning.

WHAT ARE THE NEW FINDINGS

⇒ Our study developed an econometric cost function for scaling up community-based HIV self-testing programmes for the general population in Southern Africa, using data from five countries.

⇒ Our model simplification approach showed that we could use a more parsimonious model, including scale, type of community-based intervention, percentage of men reached by the programme, distance from implementer’s warehouse and per capita Growth Domestic Product, to predict costs without significantly losing accuracy.

WHAT DO THE NEW FINDINGS IMPLY

⇒ The extrapolation of cost predictions to inform community-based HIV self-testing scale-up in Southern African countries is possible with our empirical cost function.

⇒ Our analysis adds to the literature on the trade-off between simplicity versus accuracy in cost projection methods.

INTRODUCTION

The HIV burden remains concentrated in Southern Africa, with estimated adult prevalence ranging between 10.6% in Malawi and 25.6% in Lesotho in 2018.1 Expanding access...
to HIV testing services (HTS) and ensuring linkage to prevention or timely antiretroviral therapy initiation for people living with HIV is vital to achieving epidemic control. HIV self-testing (HIVST) is an additional testing modality where an individual collects his or her own oral fluid or blood sample, conducts the test and interprets the results. HIVST has increased the uptake and frequency of testing among individuals who would not test otherwise.23

The Unitaid-funded Self-Testing ARica (STAR) Initiative led by Population Services International (PSI) started implementing HIVST delivery models in southern Africa in 2016.4 Many HIVST distribution models were evaluated, including community-based, workplace, public and private sector facility-based primary distribution strategies, and secondary distribution strategies to sexual partners and peers among key populations.5

Community-based models delivering HIVST either at people’s homes or within the community setting with mobile outreach were shown to be a convenient approach for reaching undertested groups such as young people (16–25 years old) and men.6–10 Although community-based approaches are expensive from a provider perspective, they decrease users’ costs in accessing HIV testing, in particular among working men whose time might be more expensive.9 11 12 Following the success demonstrated in the STAR Initiative, the Lesotho Ministry of Health added HIVST to its revised national HTS strategic plan for 2018–2023.15 An analysis of the costs of scaling-up HIVST (increasing the provision of HIVST kits) was needed by country planners to inform the HIVST national scale-up plans and budget in Lesotho. However, there is little guidance or empirical evidence on methods for projecting costs at scale for programming and planning.14 15

Cost functions can be derived from a production function to estimate the total cost of production given a specific output produced. The simplest cost function multiplies a single unit cost by a quantity—the commonly used ‘simple cost multiplier’ (SCM). It is a practical costing method used for high level budgeting.15 Accounting cost functions (ACFs) identify all the cost inputs to a production process (equipment, personnel, etc) over a defined costing period (usually 1 year) and categorise them as fixed, semi-fixed or variable costs in the short run or all variable in the long run.14–17 Econometric cost functions (ECF) do not follow the production process but rather apply statistical inference to predict costs. The challenge of ECF is to reflect the complexity of real-world production process with a mathematical model of inputs and outputs.14 16 In most studies, we do not have the luxury of collecting large amounts of location-specific cost data, and applications of ECF for cost predictions are rare.14 18 In the absence of detailed data, SCM is commonly used.

This study aims to fit an ECF to estimate the cost drivers of the community-based HIVST programmes in Southern Africa using data from Malawi, Zambia, Zimbabwe and South Africa. We then inform the use of ECF to predict costs at scale by comparing ECF models with different levels of data requirements. Finally, we assess the validity of our empirical ECF by comparing projected costs with observed costs at scale in Lesotho. We select Lesotho as our case study because we conducted in this country a longitudinal microcosting analysis of HIVST scale-up from a real-world intervention over 2 years of implementation.19

**METHODS**

**Setting: data sources**

We estimated the full economic costs of community-based HIVST distribution in 92 sites across Malawi, Zambia, Zimbabwe, South Africa and Lesotho (table 1).12 19 20 We collaboratively developed cost analysis methods following standard guidelines and analysed data, ensuring consistency of methods across countries.15 21 Programme expenditures supplemented by on-site observation and monitoring and evaluation data were used to estimate HIVST distribution costs.22 Costing studies in Malawi, Zambia and Zimbabwe were conducted as part of larger randomised controlled trials.12 We also conducted time and motion studies. Cost data collection and analysis methods are described in detail elsewhere.12 25 24 Some variations of the ‘community-based’ intervention were observed between countries and are described in online supplemental appendix text S1. For resources shared across different services, models or levels, we allocated expenditure using allocation factors summarised in online supplemental appendix table S1. Costs were adjusted for inflation using each country’s Consumer Price Index and presented in 2019 US$.15 25

For cost determinants (or cost drivers) presented in table 2, data on scale, number of HIVST distributors per site, efficiency, type of community-based intervention, percentages of HIVST kits distributed to men and to those who never tested for HIV were collected through the PSI monitoring and evaluation programme. Distance between distribution site and PSI headquarters, size of catchment population, HTS costs and positivity rates at nearby health facilities, per capita Growth Domestic Product (GDP) in 2019 US$, were collected as part of the STAR costing studies.12 24

**Study timelines**

Cost data were collected between June 2016 and June 2019 across all countries (figure 1). For the analysis of observed costs at scale in Lesotho, costs were collected between August 2017 and April 2019 (17 months) in five districts (Berea, Leribe, Mafeteng, Maseru and Mohale’s Hoek) where HIVST kits were distributed. We observed three scale-up phases of approximately 6 months each in Lesotho (period 1: December 2017–April 2018; period 2: May 2018–October 2018; and period 3: November 2018–April 2019).
Scale $\beta^*$ with Log $\beta^*_Q$

The data were highly skewed to the right with a heavy tail, we compared with observed costs at scale. Because the cost of a PSI fixed distributor, that is, a district and across all five districts, for each period 1–3.

Definition of site
- Catchment area of a rural public primary health clinic
- Catchment area of a rural public primary health clinic
- Ward (subdivision of a district)
- District
- Catchment area of a PSI fixed site (~1 per district), that is, a district and across all five districts, for each period 1–3.

Number of sites
- 11
- 16
- 44
- 3
- 18
- 11; 0
- 8; 8
- 44; 0
- 0; 3
- 4; 1

Location: rural; urban or periurban
- June 2016–May 2017 (12 months)
- June 2016–May 2017 (12 months)
- June 2016–May 2017 (12 months)
- June 2018–June 2019 (13 months)
- August 2017–April 2019 (17 months)

Total number of HIVST kits distributed in included sites during observation period
- 152671
- 103589
- 92559
- 154111
- 51676

Table 1 Overview of interventions by countries

| Source | Malawi | Zambia | Zimbabwe | South Africa | Lesotho | Source |
|--------|--------|--------|-----------|--------------|---------|--------|
| Per capita Gross Domestic Product (2019 US$) | $412 | $1305 | $1464 | $6001 | $1118 | 52 |
| National HIV prevalence among adults 15–59 years (%) – 2018 | 10.6 | 12.0 | 14.6 | 20.4 | 25.6 | 53–57 |
| Intervention district | Blantyre, Machinga, Mwanza and Neno | Choma, Lusaka, Ndola and Kapiri | Mberengwa, Buhera Masvingo, Chivi, Gweru, Bulilima, Gutu and Mazowe | City of Tshwane, City of Johannesburg | Masera, Berea, Leria, Mohale and Mafeteng | 58 |
| Definition of site | Catchment area of a rural public primary health clinic | Catchment area of a rural public primary health clinic | Catchment area of a PSI fixed site (~1 per district), that is, a district and across all five districts, for each period 1–3 |
| Number of sites | 11 | 16 | 44 | 3 | 18 | 58 |
| Location: rural; urban or periurban | 11; 0 | 8; 8 | 44; 0 | 0; 3 | 4; 1 | 58 |
| Analysis period | June 2016–May 2017 (12 months) | June 2016–May 2017 (12 months) | June 2016–May 2017 (12 months) | June 2018–June 2019 (13 months) | August 2017–April 2019 (17 months) | 58 |
| Total number of HIVST kits distributed in included sites during observation period | 152671 | 103589 | 92559 | 154111 | 51676 | 12 19 58 |

Econometric analysis
Econometric model specification using data from Malawi, Zambia, Zimbabwe and South Africa

We start our analysis with the conventional cost function where total costs are a function of quantity and prices. We use a linear regression approach (Ordinary Least Squares) and use average cost per HIVST kit distributed (arithmetic mean) as the dependent variable. We use average costs instead of total costs as our sample is composed of sites at various administrative levels between countries (district and catchment area of health facility), thus making comparison more intuitive and because the unit of output (HIVST kits distributed per agent monthly).

Cost determinants were selected based on the economic theory of production function, through programme observation, and the literature on cost functions for HIV care services. Cost drivers’ description, expected effect on costs and justification for inclusion in the model are presented in Table 2, following Lépine and colleagues’ approach for the categorisation of determinants. We used multiple imputation for missing data; although overall missingness was low, mean and standard deviation (SD) were comparable before/after imputation. We checked model robustness with the addition/removal of single regressors. The cost function was fitted using the R package.

Equation 1

\[ C = \beta_0 + \sum_{k=1}^{K} \beta_k Q_k + \beta_{\text{scale}} Q \text{scale} + \beta_{\text{pos}} Q_{\text{pos}} + \beta_{\text{price}} Q_{\text{price}} + \beta_{\text{dist}} Q_{\text{dist}} + \beta_{\text{pop}} Q_{\text{pop}} + \beta_{\text{site}} Q_{\text{site}} + \beta_{\text{campaign}} Q_{\text{campaign}} + \beta_{\text{eff}} Q_{\text{eff}} \]

Where:
- \( C \): total programme cost k: level of analysis: district, catchment area of health facility.
- \( \log(AC_k) \): natural logarithm of the average cost per scale variable \( Q_k \) for level k.
- \( \text{Scale} \): average number of HIVST kits distributed per month.
- \( \text{Distributor\_site} \): average number of distributors per site.
- \( \text{Campaign} \): type of intervention (campaign style vs fixed distributors).
- \( \log(\text{Efficiency}) \): natural logarithm of the number of HIVST kits distributed per agent monthly.
| Variable category | Variable name | Description | Expected effect on costs | Justification | Source |
|-------------------|---------------|-------------|--------------------------|---------------|--------|
| Dependent variable | Average costs per HIVST kit distributed including central costs | Unit costs per HIVST kit distributed including in-country central costs and start-up costs in 2019 US$ | NA | NA | 12 |
| Quantities | Scale | Number of HIVST kit distributed by site during the observation period | ± | (Dis)Economies of scale of scale | PSI |
| Site organisational characteristics | HIVST distributors | Number of full time equivalent HIVST distributor in each site | ± | Increase your coverage and # of HIVST kits distributed (so lower average costs per kit distributed), but also increase personnel costs | PSI |
| | Campaign style | Variable coded 1 if the same distributors travel from sites to sites (campaign style distribution) or 0 if they live within the community | + | In some countries, HIVST kits distribution was more conservative and restricted by campaign duration in each site, so this approach could drive costs higher due to lower volumes of kits distributed and travel costs | PSI |
| | Efficiency | Number of HIVST kits distributed per agent per month | – | The higher the number of HIVST kits distributed per agent, the more efficient they are and the lower is the cost per kit distributed | PSI |
| Characteristics of population targeted | % HIVST kits distributed to men | Number of kits distributed to men – also measure if programme is targeting well (proxy for quality) | + | Men might be harder to reach and to convince to take a kit, might lead to higher costs of provision | PSI |
| | % never tested for HIV | % of people who never tested for HIV | – | Higher knowledge of HIV status might lead to lower demand for testing, including HIVST, leading to increased average cost per kit distributed | STAR household surveys |
| Environmental characteristics | Distance | Distance from central warehouse to site in kilometres | + | Longer distance from the PSI headquarters and warehouse might lead to high costs of service provision | PSI, Google Maps |
| | Catchment population | Size of the catchment population of the site regardless of eligibility | – | Number of potential HIVST recipients affect levels of distribution potentially leading to economies of scale | PSI, Ministry of Health |
| | Positivity at health facility | Annual new HIV positive identified over total tested at nearby health facility (positivity rate) | + | If the health facilities experience high positivity rates, the demand for HIVST might be lower leading to increased average costs (higher costs to reach the last % of target population) | PSI, Ministry of Health |
| | HTS average cost at health facility | Average cost per person tested with HTS at the nearest health facility | + | Although not a determinant, a significant correlation might suggest the effect of other unobserved environmental characteristics on costs | 12 24 |
| Input price level | Price level | Per capita Growth Domestic Product in 2019 US$ | + | Proxy for input price level variation across countries | 52 |
d’Elbée M, et al. BMJ Global Health 2021;6:e005554. doi:10.1136/bmjgh-2021-005554

Perc_men: percentage of HIVST kits distributed to men out of total distribution volumes.

Perc_never_tested: percentage of HIVST kits distributed to people who never tested before out of total distribution volumes.

Distance: distance of site from implementer’s central warehouse (in kilometres).

Population: size of total population at the site.

Positivity: positivity of rapid HIV testing (number of HIV-positive case found out of total number of persons tested) at nearby health facilities.

Cost_facility: average cost per facility-based HIV testing session at nearby health facilities.

Price_level: proxy for input price level variation across countries based on per capita GDP.

\( \beta_0 \): model intercept.

\( \beta_1 - \beta_{13} \): model coefficients computed using empirical dataset.

Q\( _k \): quantity of units for level k: number of HIVST kits distributed.

Using the model to predict costs at scale in Lesotho

Coefficients in a log-linear model are the estimated percentage change—elasticity—in the dependent variable for a unit change in the independent variable.41 42

We used the ‘predict’ function in R package to estimate average cost for various scale values. We used exponential function to back transform estimated average costs as our error terms were normally distributed.43

We compared total costs at ‘national’ (all five districts) and district level to allow for comparison between observed costs (scale-up periods 1, 2 and 3) and predicted costs. The likelihood ratio test (LRT), comparing the goodness of fit of two statistical models, was used to assess whether we could simplify the model (ie, reduce the number of parameters in our regression model) for cost projections.

Patient and public involvement

To conduct our costing study from a provider perspective, it was not appropriate to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research.

Figure 1  STAR costing period and data sources by country for each cost analysis. HIVST, HIV self-testing; MA, Malawi; STAR, HIVSelf-Testing AfRica; Za, Zambia; Zi, Zimbabwe.

Ethical approvals

The trials are registered under the Clinical Trials Network (ClinicalTrials.gov) under registration numbers NCT02793804, NCT02718274 and Pan African clinical trials registry PACTR201607001701788 for Malawi, Zambia and Zimbabwe. Informed consent was obtained from all individual participants included in the time and motion study.

RESULTS

Descriptive statistics

Descriptive statistics (mean, SD, min and max) of data are presented for the full sample and for each country in table 3. Sample mean of average cost per kit distributed was $14.58 (median: $13.54). On average, each site had 26 (range: 2–272) distributors and distributed 993 (range: 160–5904) kits. Part of the strategy was to reach men, and those who had never tested before, these groups made up, on average, 48% and 12%, respectively, of kit recipients. Average distance of site to warehouse was 162 km, population size of 672 429 inhabitants and, finally, positivity rate of 8% and the cost of provider-delivered HIV testing was $6.22 per person tested at nearby health facilities.

Determinants of HIVST average costs at programme level and model simplification

We retained a combination of three scale variables, normally distributed, quadratic and cubic, because they explained the largest share of the variance (R² was the highest).44 45

We explored several functional forms for other cost determinants; only efficiency was log-transformed as it improved model fit. Other determinants were kept with a normal distribution. The correlation matrix showed high correlation between population and scale, between distributors and campaign style, and low or no correlation otherwise (online supplemental appendix figure S1); therefore, the variables population and distributors were excluded. Multicollinearity was assessed on the remaining cost drivers using the variance inflation factor (VIF) test and was acceptable (mean VIF: 2.94). We tested
Table 3  Descriptive statistics

| Number of sites (N) | Variables | Mean | SD  | Min  | Max  | Mean | SD  | Min  | Max  | Mean | SD  | Min  | Max  |
|---------------------|-----------|------|-----|------|------|------|-----|------|------|------|-----|------|------|
|                     | Total sample | 92   |     |      |      | 11   |     |      |      | 16   |     |      |      |
| Variables           |           |      |     |      |      |      |     |      |      |      |     |      |      |
| Average cost per HIVST kit distributed (including central costs) |          | 14.58 | 2.8 | 7.2  | 54.44 | 10.65 | 2.93 | 7.20 | 17.04 | 21.11 | 10.73 | 7.91 | 50.01 |
| Average cost per HIVST kit distributed (excluding central costs) |          | 10.73 | 1.7 | 4.52 | 41.49 | 5.56 | 1.03 | 4.52 | 7.52 | 12.39 | 5.36 | 6.40 | 26.50 |
| Scale               |           | 1319 | 819 | 160  | 5904 | 1045 | 1005 | 380  | 3511 | 589  | 398  | 160  | 1859 |
| HIVST distributors   |           | 26   | 26  | 2    | 40   | 13   | 8   | 6    | 31   | 9    | 3    | 5    | 18   |
| Campaign style      |           | 0.56 | 0.5 | 0    | 1    | 0    | 0   | 0    | 0    | 0    | 0    | 0    | 0    |
| Efficiency          |           | 109  | 56  | 13   | 486  | 75   | 22  | 48   | 113  | 64   | 23   | 27   | 103  |
| % HIVST kits distributed to men |          | 48   | 8   | 31   | 76   | 50   | 3   | 45   | 55   | 56   | 25   | 33   | 76   |
| % HIVST kits distributed to people who never tested for HIV |          | 12   | 2   | 0    | 22   | 18   | 3   | 11   | 22   | 18   | 3    | 13   | 21   |
| Distance            |           | 162  | 35  | 3    | 647  | 85   | 55  | 20   | 180  | 210  | 122  | 11   | 348  |
| Catchment population |           | 672429 | 824163 | 549 | 4949347 | 24007 | 21804 | 4452 | 82581 | 488379 | 50924 | 10996 | 172753 |
| Positivity          |           | 0.08 | 0.03 | 0     | 0.62 | 0.09 | 0.04 | 0.03 | 0.14 | 0.09 | 0.07 | 0.00 | 0.27 |
| HTS average cost    |           | 6.22 | 2.5 | 2.3  | 34.78 | 3.97 | 1.09 | 2.64 | 5.81 | 4.45 | 1.41 | 2.49 | 7.17 |
| Number of sites (N) |           |      |     |      |      |      |     |      |      |      |     |      |      |
|                     | Zimbabwe | 44   |     |      |      |      |     |      |      |      |     |      |      |
| Variables           |           |      |     |      |      |      |     |      |      |      |     |      |      |
| Average cost per HIVST kit distributed (including central costs) |          | 15.79 | 7.32 | 10.19 | 54.44 | 13.54 | 5.36 | 9.69 | 19.67 | 11.79 | 3.79 | 6.97 | 22.81 |
| Average cost per HIVST kit distributed (excluding central costs) |          | 11.65 | 5.66 | 7.44 | 41.49 | 12.59 | 5.38 | 8.76 | 18.74 | 11.45 | 3.64 | 6.80 | 21.96 |
| Scale               |           | 1052 | 401 | 160  | 2101 | 2901 | 2636 | 971  | 5904 | 1009 | 1007 | 188  | 4184 |
| HIVST distributors   |           | 23   | 7   | 5    | 40   | 10   | 7   | 2    | 14   | 75   | 71   | 10   | 272  |
| Campaign style      |           | 1    | 0   | 1    | 1    | 0    | 0   | 0    | 0    | 0    | 0    | 0    | 0    |
| Efficiency          |           | 47   | 14  | 13   | 80   | 346  | 155  | 130  | 486  | 15   | 7    | 5    | 40   |
| % HIVST kits distributed to men |          | 44   | 4   | 38   | 55   | 51   | 12  | 37   | 60   | 38   | 9    | 31   | 56   |
| % HIVST kits distributed to people who never tested for HIV |          | 12   | 4   | 5    | 21   | 11   | 8   | 3    | 18   | 2    | 1    | 0    | 2    |
for heteroscedasticity using the Breusch-Pagan test and failed to reject the null hypothesis (p>0.05); therefore, heteroscedasticity was not present in the model.

We progressively added cost determinants to our model starting with scale, followed by organisational characteristics, characteristics of the population reached, environmental factors and price level (table 4). Major cost determinants were scale, campaign-style distribution, % of kits distributed to men, distance from the implementer’s warehouse and price level (model 5). We found a negative association between scale and average cost. If scale increases by 100 HIVST kits distributed, average cost decreases by 0.16%. Campaign-style distribution increased costs by 19%. An increase in 1% of kits distributed to men increased average cost by 0.67%. An increase of the distance between the implementer’s warehouse and HIVST distribution areas by 1 km increased costs by 0.01%. Finally, an increase of per capita GDP (price level) by $10 led to an increase of average cost by 0.01%.

For the model simplification analysis, we removed % never tested, positivity and HTS costs at health facility in model 6, as these determinants were not significant (table 5). Model 5 did not significantly improve fit to the data than Model 6 (LRT: p value: 0.82). Additionally, model 7, where efficiency was removed, did not significantly reduced goodness of fit than model 6 (LRT: p value: 0.67).

### Observed costs at scale in Lesotho

The cost analysis (online supplemental appendix table S2) was conducted for each of the three costing periods at national and district levels. The main cost drivers identified were personnel costs at national level (9%, 12% and 9% for periods 1, 2 and 3 respectively), district level (29%, 29% and 31%) and community outreach (27%, 28% and 21%), as well as HIVST kits costs (25%, 20% and 30%). Overall, HIVST distribution volumes were decreasing between periods 1 and 2 (14 099 and 12 471 kits), then increasing between periods 2 and 3 (12 471 and 25 106 kits). Between districts, we observed wide variation in HIVST kit distribution volumes ranging from 1130 kits (Mohale’s Hoek, period 2) to 7958 kits (Leribe, period 3). At national level, average cost per kit distributed varied between periods: $10.69, $13.71 and $9.12 in periods 1, 2 and 3, respectively. At district level, wide variation was observed with average cost ranging from $6.97 (Leribe, period 3) to $22.81 (Berea, period 2).

### Predicting costs at scale in Lesotho using the ECF with varying levels of complexity and comparison with observed costs at scale

We present observed total costs for each scale-up period at national and district level in Lesotho, against projected costs from models 5–7 (figure 2). Overall cost projections at given scale were close to observed costs at district level and at national level in period 1, whereas we report some discrepancies at national level in periods 2 and 3. The
| Parameters | Model 1 | | Model 2 | | Model 3 | | Model 4 | | Model 5 |
|---|---|---|---|---|---|---|---|---|---|
| | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| Constant | 3.501*** | 0.125 | 3.428*** | 0.335 | 3.135*** | 0.390 | 2.395*** | 0.405 | 3.153*** | 0.437 |
| Scale (in thousands) | −1.261*** | 0.250 | −1.935*** | 0.316 | −1.889*** | 0.319 | −1.529*** | 0.314 | −1.578*** | 0.291 |
| Scale^2 (in millions) | 0.388*** | 0.132 | 0.684*** | 0.149 | 0.656*** | 0.150 | 0.492*** | 0.146 | 0.553*** | 0.137 |
| Scale^3 (in billions) | −0.036** | 0.016 | −0.068*** | 0.018 | −0.064*** | 0.018 | −0.046*** | 0.017 | −0.056*** | 0.016 |
| Campaign-style | 0.364*** | 0.101 | 0.392*** | 0.104 | 0.169 | 0.108 | 0.174* | 0.100 | 0.511** | 0.221 |
| Efficiency | 0.050 | 0.095 | 0.071 | 0.093 | 0.171* | 0.095 | −0.049 | 0.109 | −0.097 | 0.748 |
| % HIVST kits distributed to men | 0.533** | 0.246 | 0.737*** | 0.228 | −0.557 | 0.769 | −1.236* | 0.722 | −0.097 | 0.748 |
| % HIVST kits distributed to people who never tested for HIV | 0.050 | 0.095 | 0.071 | 0.093 | 0.171* | 0.095 | −0.049 | 0.109 | −0.097 | 0.748 |
| Distance (in thousands) | 1.062*** | 0.279 | 0.603** | 0.292 | 0.603** | 0.292 | 0.177 | 0.327 | 0.177 | 0.327 |
| Positivity | −0.001 | 0.006 | −0.004 | 0.006 | 0.071 | 0.352 | 0.177 | 0.327 | 0.177 | 0.327 |
| HTS average cost | 0.139*** | 0.041 | 0.139*** | 0.041 | 0.139*** | 0.041 | 0.139*** | 0.041 | 0.139*** | 0.041 |
| No. of observations | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 |
| R^2 | 0.51 | 0.63 | 0.66 | 0.74 | 0.78 | 0.74 |
| R^2 adjusted | 0.49 | 0.60 | 0.62 | 0.69 | 0.74 |

**P<0.01, *P<0.05, *P<0.10.**
HIVST, HIV self-testing; SE, Standard error.
comparison of projected total costs also showed that more parsimonious ECF (model 7) were not less accurate than more data hungry ECF (model 5). Simplified models were more precise due to narrower 95% CIs but would sometimes not include the observed costs in their range (model 5 vs model 7: all districts – period 2).

**DISCUSSION**
Our study developed an econometric cost function for scaling up community-based HIVST programmes for the general population in Southern Africa, using data from five countries. Our results suggest that programme design characteristics, including the scale of HIVST

**Table 5** Model simplification approach

| Parameters                        | Model 5        | Model 6        | Model 7        |
|-----------------------------------|----------------|----------------|----------------|
| Constant                          | Estimate       | SE             | Estimate       | SE             | Estimate       | SE             |
|                                   | 3.153***       | 0.437          | 3.110***       | 0.418          | 2.963***       | 0.191          |
| Scale (in thousands)              | −1.578***      | 0.291          | −1.630***      | 0.271          | −1.662***      | 0.257          |
| Scale \(\times 2\) (in millions) | 0.553***       | 0.137          | 0.575***       | 0.129          | 0.585***       | 0.126          |
| Scale \(\times 3\) (in billions) | −0.056***      | 0.016          | −0.059***      | 0.015          | −0.060***      | 0.015          |
| Efficiency                        | 0.174*         | 0.100          | 0.187**        | 0.093          | 0.205**        | 0.080          |
| % HIVST kits distributed to men   | −0.049         | 0.109          | −0.037         | 0.092          |                |                |
| % HIVST kits distributed to people| 0.511**        | 0.221          | 0.519**        | 0.216          | 0.542**        | 0.208          |
| Distance (in thousands)           | 0.603**        | 0.292          | 0.582**        | 0.245          | 0.623***       | 0.222          |
| Positivity                        | 0.177          | 0.327          |                |                |                |                |
| HTS average cost                  | −0.004         | 0.006          |                |                |                |                |
| Price level (in thousands)        | 0.139***       | 0.041          | 0.133***       | 0.035          | 0.126***       | 0.029          |
| No. of obs.                       | 74             | 74             | 74             |                |                |                |
| \(R^2\)                          | 0.78           | 0.77           | 0.77           |                |                |                |
| \(R^2\) adjusted                 | 0.74           | 0.75           | 0.75           |                |                |                |
| Likelihood ratio test: model 5 versus model 6, and model 6 versus model 7 | Difference of \(\chi^2\) values (df) | 0.93 (3) | 0.18 (1) |
| P value                           | 0.82           | 0.67           |                |                |                |                |

***P<0.01, **p<0.05, *p<0.10; df calculations: model 5 versus model 6: 13–10=3, model 6 versus model 7: 10–9=1.

HIVST, HIV self-testing; SE, Standard error.

**Figure 2** National and district level observed and projected (models 5–7) HIVST total costs by scale-up period in Lesotho (error bars: 95% CIs). HIVST, HIV self-testing.
distribution, type of community-based intervention, characteristics of the population targeted with HIVST (men), distance from implementer’s headquarter and per capita GDP can be used to predict average costs. These findings are consistent with previous studies on HIV prevention cost functions highlighting the role of scale as the major cost determinant among other cost drivers. We also found that reaching men was associated with higher average HIVST distribution costs. Previous studies have shown that men’s uptake of community HIV testing is often lower than uptake in women, as men are less likely to be present when mobile testing teams visit households, or might be more reluctant to take a kit, therefore increasing provision costs. In addition, it is increasingly relevant to account for decreasing returns to scale for epidemics such as HIV or malaria where testing efforts have increased over decades, making it more expensive to reach the last percentage of the target population, due to the last remaining untested living in remote areas, or being part of harder to reach population groups.

Our model simplification approach showed that we could use a more parsimonious model to predict costs without significantly losing accuracy. This is particularly relevant as in most studies, we have scant opportunity to collect large amounts of location-specific cost data, and the necessary background information (e.g., percentage of population who never tested at the community level) might not exist. The per capita GDP variable showed that our cost function could potentially be applied to other countries. This is in line with the study by Cerecero-García and colleagues that used per capita GDP as a determinant to predict HIV treatment average costs in out-of-sample countries. The extrapolation of cost projections to other Southern African countries seems possible with our parsimonious empirical cost function; however, it would probably require additional or different variables in other settings such as in West Africa.

The use of ECF to predict costs at scale in the context of financial planning and budgeting is limited in the development economics literature. In a study from 2018, Berman and colleagues used a combination of ECF and ACF (using the normative costing approach incorporated in the WHO’s OneHealth tool) to provide low and high estimates of financial needs to plan Ethiopia’s primary healthcare system. The authors suggested that ECF could provide a low estimate of resource needs due to limited inclusion of capital investments, future changes in services offered to meet changes in health needs and future improvements potentially required for the quality of services provided. Their findings suggest that our cost projections based on ECF could potentially underestimate the amount of resources needed.

Our findings in Lesotho for the observed cost analysis across scale-up periods are consistent, in terms of average costs and cost composition, with the existing literature on HIVST costs in the region, ranging from US$8.15 per kit distributed in Malawi to US$16.42 in Zambia. This suggests that they can be used as comparators with forecast costs analysis. Overall, ECF gave highly accurate and consistent scale-up cost estimates compared with observed costs at district level, suggesting a good predictive capacity of our empirical cost function. At higher scale (national level), cost predictions were close to observed costs in period 1 but were slightly below observed costs in period 2 and above in period 3. HIVST implementation and scale-up in Lesotho went through varying levels of efficiency (i.e., number of HIVST kits distributed by agents monthly) and was explained by an HIVST implementation strategy maturing over time with important impact on programme costs. HIVST scale-up went through an inefficient phase in period 2 with limited HIVST distribution volumes because of the time spent by providers to offer individual onsite counselling and supervision for self-testing at the mobile outreach. Period 2 was then followed by a more efficient phase, when self-testing booth were introduced at the mobile outreach (period 3) allowing staff to supervise onsite self-testing of many clients at the same time. Although we account for efficiency as a cost determinant in our models 5–7, it was not significant, maybe related to our relatively small sample size or the small role that distributor salaries play in overall costs. Additionally, our ECF is highly sensitive to scale (strongest cost driver), explained by observed large economies of scale in our country sample (Malawi, Zambia and Zimbabwe), which is why the ‘efficiency’ effect is only observed at larger scale (national and not district level). Consequently, during the inefficient period 2, our projected costs are underestimating observed costs (predicting higher economies of scale than actually observed) and vice versa in period 3.

Our study has several limitations. First, although we use primary data and standardised cost data collection and analysis methods, we have an unbalanced sample of sites. While some countries contributed with a large sample of sites, others only included a few observations. We assume that because the same implementer (PSI) is working in the region with similar financial reporting system, this unbalance would not affect our modelling approach. Second, we use an observed scale-up period in Lesotho that evolved over time as programme matures, limiting our assessment of cost projections’ accuracy. Third, we do not have country-specific panel data; therefore, time-dependent unobserved cost determinants are ignored for the econometric analysis. Fourth, while these estimates provide some likely key drivers of costs and their direction, we do expect our cost projections to be more accurate within settings where the main change relates to variations in scale. Fifth, our cost analysis is limited to average costs per kit distributed as the private nature of the HIVST did not allow us to estimate the costs of identifying new HIV-positive individuals or those HIV-positive individuals...
linked to treatment through HVIST, limiting the applications of our findings by policymakers and programme planners.

Our empirical analysis adds to the discussion on the trade-off between simplicity versus accuracy in cost projection method. Further research should estimate health intervention costs at scale using the three different cost function methods (SCM, ECF and ACF) and compare cost predictions at various scales, ultimately to inform the choice of a cost projection method based on the intended use of the cost estimates.

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Appendix Text - Narrative description of the community-based HIVST distribution models across countries – PSI New Start programme in all countries (adapted from Mangenah et al., 2019; d’Elbée et al., 2020)

Malawi

In Malawi, a randomised controlled trial (RCT) was conducted in rural areas of Blantyre, Machinga, Mwanza and Neno districts in Southern Malawi and comprised a total trial population of approximately 62,500 residents. Catchment populations of 22 public rural primary health clinics (PHCs) were randomized 1:1 to either HIVST or standard of care. In the 11 HIVST intervention communities, residents had access to community-based distribution agent’s (CBDA) delivered HIVST (door-to-door) or the option to go to the CBDA’s home over a continuous 1-year period (June 2016 to May 2017). CBDAs were paid an incentive of United States Dollar (US) $0.15 [100 Malawi Kwacha (MWK)] per kit distributed. This was integrated into their regular activities distributing contraceptives and other health products. In all sites, residents could access free HTS and ART if HIV-positive, through the PHCs.

Zambia

In Zambia, residents across 16 rural community sites had access to CBDA delivered HIVST or the option to go to the CBDA’s home over a continuous 1-year period (July 2016 to June 2017), reaching a total target adult population of 416,294 across Ndola, Kapiri, Lusaka and Choma districts. In this hub and spoke model CBDAs were linked to specific clinics and worked in their surrounding catchment populations. CBDAs were initially paid a monthly allowance of US$78 [750 Zambia Kwacha (ZMK)] independent of performance; this was later supplemented by a US$0.21 (2 ZMK) incentive per used kit returned. Though only six sites were included in the RCT, costs were evaluated for all 16 sites.

Zimbabwe

In Zimbabwe, the RCT was conducted across eight rural district sites with a total trial population of approximately 224,116 residents. Forty-four geographically defined wards were randomized 1:1 to either linkage intervention (HIVST plus distributor incentive for linkage events) or control (HIVST with fixed distributor allowance) clusters. HIVST was delivered across sites through one-off 4-6 week campaigns, moving sequentially from one district to the other between August 2016, and May 2017. In each district, new CBDAs were recruited and trained for three days. CBDAs then each distributed a specific number of tests proportional to their confined catchment area. Each CBDA was equipped with a tablet to demonstrate how to conduct a self-test through a video and to collate data on each self-tester.

At one to two weeks following HIVST distribution, the routine PSI mobile outreach service offered HIV confirmatory testing for individuals with reactive HIVST test result and HIV treatment referral to public sector health facilities for individuals with confirmed HIV positive results, including other services such as family planning and screening for non-communicable diseases. All CBDAs received a fixed allowance of USD$50, with an additional US$0.20 incentive for those in the linkage intervention arm per HIVST positive tester who linked for post-test services at PSI mobile outreach services. There was no compensation given to HIV negatives linking to post-test services. We estimated the cost of HIVST distribution in both intervention and control sites. The cost of providing confirmatory testing at outreach services is not included in this study, for consistency across countries.
Lesotho

HIVST provision was done through PSI mobile outreaches or mobile team conducting door-to-door HTS and HIVST distribution in five priority districts of Lesotho (Maseru, Berea, Leribe, Mafeteng, and Mohale’s Hoek).

In the case of outreach based activities, the client is offered the option to self-test or to receive provider delivered HTS at the mobile outreach. The HTS provider collects client data based on the HIVST register. Clients who opt for self-testing have the choice of testing on site or taking the kit away for testing at their convenience. Clients are encouraged to test at mobile outreach where possible to maximize review of test result with HTS provider.

Clients who choose to self-test on-site are given a self-test package and access to testing tent where they can self-test in private. If the result is positive, the client is offered confirmatory HIV Testing by the HTS provider at the site. If confirmatory results are positive, the client is referred to the preferred nearby health facility. All confirmed clients living with HIV are offered HIV self-test kit for secondary distribution to their sexual partner(s) or home visit for index HIV testing.

If HIV self-test is negative, the client is counselled on HIV prevention and offered preventive methods including VMMC for males, PrEP if eligible according to guidelines and consistent & correct condom use. The clients with a negative HIV status are also counselled on need for subsequent repeat testing according to risk profile outlined in the national guidelines. Clients who opt to do self-test off site also follow similar processes for clients who test off site at New Start.

South Africa

Between Jan 2018 and Oct 2019, 158,997 HIVST kits were distributed by Society for Family Health - SFH (PSI affiliate) in community-based models through fixed-point distribution in the districts of City of Tshwane, City of Johannesburg, and Dr Kenneth Kaunda.

HIVST was integrated with existing community-based HTS activity platforms where HIVST was offered to individual clients after demonstration of how to use it as an HTS screening option. At the time of receiving the package clients were shown an instructional video on a tablet or smartphone. Basic information were collected from the client, including demographics and history of HIV testing; using REDCap™. Clients could choose to self-test themselves onsite or with assistance of the counsellor. Clients who chose to self-test onsite were given a HIVST kit with validated instructions and access to a private space. Clients were encouraged to disclose their HIVST results to the counsellor. Clients who self-tested negative were referred for prevention services and clients who had a reactive self-test were confirmed and referred for further managed health care.
## Appendix Table S1. Allocation factors from STAR expenditures to model, and model to districts

| Input types          | STAR expenditure - Allocation of incremental HIVST costs | STAR expenditure - Allocation factors - Model to districts |
|----------------------|----------------------------------------------------------|----------------------------------------------------------|
| **Start-up**         |                                                          |                                                          |
| S1: Training         | Not applicable                                           | % of participants to the training                        |
| S2: Sensitisation    | Not applicable                                           | Equally across districts                                 |
| S3: Start-up other   | Not applicable                                           | % of HIVST kits distributed                             |
| **Capital**          |                                                          |                                                          |
| A: Building & storage| Full: Direct expenditures                                | % of direct expenditure                                  |
|                     | Incremental: Direct expenditure                          |                                                          |
| B: Equipment         | Full: % of HTS versus HIVST activities                   | % of direct expenditure                                  |
|                     | Incremental: Direct expenditure                          |                                                          |
| **Recurent**         |                                                          |                                                          |
| E: Personnel & Per diems – HQ (international and national) | Full: Direct expenditures                                | Equally across districts                                 |
| E: Personnel & Per diems – HQ (district)                  | Incremental: Direct expenditures                        | % of HIVST distributors                                  |
| E: Personnel & Per diems – HQ (field)                     | Full: Direct expenditures                                | % of HIVST distributors                                  |
| F: Supplies (including HIVST kits)                        | Incremental: Direct expenditures                        | % of HIVST kits distributed                             |
| G: Vehicle operation, maintenance & transport             | Full: Direct expenditures                                | % of mileage (HQ to district HQ) and # of cars per site  |
| H: Building operation/maintenance                          | Full: Direct expenditures                                | % of direct expenditure                                  |
| K: Other recurrent                                          | Full: Direct expenditures                                | % of HIVST kits distributed                             |
|                     | Incremental: Direct expenditures                        |                                                          |
Appendix Figure S1. Correlation matrix
### Appendix Table S2. Observed incremental HIVST costs for each of the three costing periods (period 1: December 2017 – April 2018, period 2: May 2018 – October 2018, period 3: November 2018 – April 2019) at national and district levels in Lesotho (1/3)

| # of implementation month | 5 districts | 6 districts | 6 districts | Berea | Berea | Berea |
|---------------------------|-------------|-------------|-------------|-------|-------|-------|
|                          | Dec 17 – Apr 18 | May 18 – Oct 18 | Nov 18 – Apr 19 | Dec 17 – Apr 18 | May 18 – Oct 18 | Nov 18 – Apr 19 |
| **Input types**           | Costs | % | Costs | % | Costs | % | Costs | % | Costs | % |
| **Start-up**              |       |   |       |   |       |   |       |   |       |   |
| S1: Training              | $574.57 | 0% | $574.57 | 0% | $574.57 | 0% | $68.31 | 0% | $68.31 | 0% |
| S2: Sensitisation         | $188.75 | 0% | $188.75 | 0% | $188.75 | 0% | $37.75 | 0% | $37.75 | 0% |
| S3: Start-up other         | $4,039.27 | 3% | $4,039.27 | 2% | $4,039.27 | 2% | $786.35 | 3% | $786.35 | 2% |
| **Start-up - sub-total**  | $4,802.59 | 3% | $4,802.59 | 3% | $4,802.59 | 2% | $892.41 | 3% | $892.41 | 3% |
| **Capital**               |       |   |       |   |       |   |       |   |       |   |
| A: Building & storage     | $64.75 | 0% | $1,374.58 | 1% | $1,367.43 | 1% | $11.51 | 0% | $244.25 | 1% | $242.98 | 1% |
| B1: Equipment - National  | $0.00 | 0% | $32.43 | 0% | $0.00 | 0% | $0.00 | 0% | $5.76 | 0% | $0.00 | 0% |
| B2: Equipment - District   | $315.96 | 0% | $588.52 | 0% | $2,373.13 | 1% | $56.15 | 0% | $104.58 | 0% | $421.69 | 1% |
| **Capital - sub-total**   | $380.71 | 0% | $1,995.53 | 1% | $3,740.57 | 2% | $67.65 | 0% | $354.59 | 1% | $664.68 | 1% |
| **Recurrent**             |       |   |       |   |       |   |       |   |       |   |
| E1: Personnel & Per diems - HQ - International | $7,623.82 | 5% | $7,166.08 | 4% | $3,502.23 | 2% | $1,524.76 | 5% | $1,433.22 | 4% | $700.45 | 1% | $1,433.22 | 4% | $700.45 | 1% |
| E2: Personnel & Per diems - HQ - National | $13,966.18 | 9% | $20,438.02 | 12% | $2,046.76 | 9% | $7,293.24 | 9% | $4,087.60 | 12% | $4,093.95 | 9% |
| E3: Personnel & Per diems - HQ - District | $43,608.84 | 29% | $50,170.86 | 29% | $70,638.18 | 31% | $9,344.75 | 30% | $10,750.90 | 31% | $15,136.75 | 32% |
| E4: Personnel & Per diems - Field | $40,247.13 | 27% | $48,296.56 | 28% | $48,296.56 | 21% | $8,624.39 | 28% | $10,349.26 | 29% | $15,136.75 | 32% |
| F1: Supplies              | $465.80 | 0% | $165.28 | 0% | $165.28 | 0% | $90.68 | 0% | $32.18 | 0% | $33.68 | 0% |
| F2: HIVST kits            | $38,255.60 | 25% | $33,838.26 | 20% | $68,121.51 | 30% | $7,447.51 | 24% | $6,587.55 | 19% | $13,261.74 | 28% |
| G: Vehicle operation, maintenance & transport | $422.02 | 0% | $1,311.18 | 1% | $3,802.08 | 2% | $67.17 | 0% | $208.68 | 1% | $605.11 | 1% |
| H: Building operation/maintenance | $284.57 | 0% | $666.66 | 0% | $1,282.08 | 1% | $50.57 | 0% | $116.80 | 0% | $227.82 | 0% |
| K: Other recurrent costs  | $664.84 | 0% | $2,080.78 | 1% | $4,250.60 | 2% | $129.43 | 0% | $405.08 | 1% | $827.50 | 2% |
| **Recurrent - sub-total** | $145,538.81 | 97% | $164,123.68 | 96% | $220,536.00 | 96% | $30,072.49 | 97% | $33,971.16 | 96% | $45,236.26 | 97% |
| **Total HIVST costs**     | $150,722.11 | 100% | $170,921.79 | 100% | $229,079.16 | 100% | $31,032.55 | 100% | $35,218.16 | 100% | $46,793.34 |
| HIVST kits distributed    | $14,099 | 9.3% | $12,471 | 7.3% | $25,106 | 11.2% | $3,656 | 11.7% | $1,544 | 4.4% | $4,258 |
| Average HIVST costs       | $10.69 | 0.7% | $13.71 | 0.8% | $9.12 | 0.4% | $8.49 | 0.2% | $2.81 | 0.8% | $10.99 |
### Appendix Table S2.
Observed incremental HIVST costs for each of the three costing periods (period 1: December 2017 – April 2018, period 2: May 2018 – October 2018, period 3: November 2018 – April 2019) at national and district levels in Lesotho (2/3)

| # of implementation month | Leribe | Mafeteng | Leribe | Mafeteng | Leribe | Mafeteng |
|---------------------------|--------|----------|--------|----------|--------|----------|
| Input types               | Costs  | %        | Costs  | %        | Costs  | %        |
| S1: Training              | $130.58 | 0%       | $130.58 | 0%       | $130.58 | 0%       | $88.40       | 0%       | $88.40       | 0%       |
| S2: Sensitisation         | $37.75  | 0%       | $37.75  | 0%       | $37.75  | 0%       | $37.75       | 0%       | $37.75       | 0%       |
| S3: Start-up other        | $987.18 | 3%       | $987.18 | 2%       | $987.18 | 2%       | $639.74      | 3%       | $639.74      | 3%       |
| **Start-up - sub-total**  | $1,155.52 | 3%       | $1,155.52 | 3%       | $1,155.52 | 4%       | $765.89      | 3%       | $765.89      | 2%       |
| Capital                   |        |          |        |          |        |          |
| A: Building & storage     | $16.16  | 0%       | $343.00 | 1%       | $341.22 | 1%       | $10.03       | 0%       | $212.98      | 1%       | $211.87      | 1%       |
| B1: Equipment - National  | $0.00   | 0%       | $8.09   | 0%       | $0.00   | 0%       | $0.00        | 0%       | $5.02        | 0%       | $0.00        | 0%       |
| B2: Equipment - District  | $78.84  | 0%       | $146.86 | 0%       | $592.18 | 1%       | $48.96       | 0%       | $91.19       | 0%       | $367.70      | 1%       |
| **Capital - sub-total**   | $95.00  | 0%       | $497.95 | 1%       | $933.40 | 2%       | $58.99       | 0%       | $309.19      | 1%       | $579.58      | 2%       |
| Recurrent                 |        |          |        |          |        |          |
| E1: Personnel & Per diems - HQ - International | $1,524.76 | 4%       | $1,433.22 | 4%       | $700.45 | 1%       | $1,524.76    | 7%       | $1,433.22    | 6%       | $700.45      | 2%       |
| E2: Personnel & Per diems - HQ - National | $2,793.24 | 8%       | $4,087.60 | 10%      | $4,093.95 | 7%       | $2,793.24    | 13%      | $4,087.60    | 16%      | $4,093.95    | 12%      |
| E3: Personnel & Per diems - HQ - District | $10,760.62 | 30%      | $12,379.82 | 30%      | $17,430.20 | 31%      | $5,380.31    | 25%      | $6,189.91    | 25%      | $8,715.10    | 26%      |
| E4: Personnel & Per diems - Field | $9,931.11 | 28%      | $11,917.33 | 29%      | $11,917.33 | 21%      | $4,965.56    | 23%      | $5,359.31    | 22%      | $10,789.10   | 18%      |
| F1: Supplies              | $113.84 | 0%       | $40.39  | 0%       | $42.28  | 0%       | $73.77       | 0%       | $26.18       | 0%       | $27.40       | 0%       |
| F2: HIVST kits            | $9,349.54 | 26%      | $8,269.96 | 20%      | $16,648.67 | 30%      | $6,058.93    | 28%      | $5,359.31    | 22%      | $10,789.10   | 32%      |
| G: Vehicle operation, maintenance & transport | $129.41 | 0%       | $402.08  | 1%       | $1,665.92 | 2%       | $82.81       | 0%       | $257.29      | 1%       | $746.08      | 2%       |
| H: Building operation/maintenance | $71.01   | 0%       | $163.86 | 0%       | $319.92 | 1%       | $44.09       | 0%       | $101.75      | 0%       | $198.65      | 1%       |
| K: Other recurrent costs  | $162.48 | 0%       | $508.53 | 1%       | $1,038.83 | 2%       | $105.30      | 0%       | $329.55      | 1%       | $673.21      | 2%       |
| **Recurrent - sub-total** | $34,836.02 | 97%      | $39,202.80 | 96%      | $53,357.56 | 96%      | $21,028.77   | 96%      | $23,743.47   | 96%      | $31,902.60   | 96%      |
| Total HIVST costs         | $36,086.54 | 97%      | $40,856.27 | 96%      | $55,446.47 | 96%      | $21,853.65   | 96%      | $24,818.55   | 96%      | $33,248.06   | 96%      |
| HIVST kits distributed    | 3,270   | 0%       | 3,064   | 0%       | 7,958   | 0%       | 1,411        | 0%       | 2,866        | 0%       | 3,625        | 0%       |
| Average HIVST costs       | $11.04  | $13.33   | $6.97   | $15.49   | $8.66   | $9.17     |

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### Appendix Table S2. Observed incremental HIVST costs for each of the three costing periods (period 1: December 2017 – April 2018, period 2: May 2018 – October 2018, period 3: November 2018 – April 2019) at national and district levels in Lesotho (3/3)

| # of implementation month | Maseru |   |   | Mohale |   |   |
|---------------------------|--------|---|---|--------|---|---|
|                           | Dec 17 - Apr 18 | May 18 - Oct 18 | Nov 18 - Apr 19 | Dec 17 - Apr 18 | May 18 - Oct 18 | Nov 18 - Apr 19 |
| **Input types**           | Costs | % | Costs | % | Costs | % | Costs | % | Costs | % | Costs | % |
| **Start-up**              |       |   |       |   |       |   |       |   |       |   |       |   |
| S1: Training              | $245.10 | 1% | $245.10 | 0% | $245.10 | 0% | $42.19 | 0% | $42.19 | 0% | $42.19 | 0% |
| S2: Sensitisation         | $37.75 | 0% | $37.75 | 0% | $37.75 | 0% | $37.75 | 0% | $37.75 | 0% | $37.75 | 0% |
| S3: Start-up other        | $1,150.76 | 3% | $1,150.76 | 2% | $1,150.76 | 2% | $475.23 | 3% | $475.23 | 2% | $475.23 | 2% |
| **Start-up - sub-total**  | $1,433.60 | 3% | $1,433.60 | 3% | $1,433.60 | 2% | $555.17 | 3% | $555.17 | 3% | $555.17 | 2% |
| **Capital**               |       |   |       |   |       |   |       |   |       |   |       |   |
| A: Building & storage     | $20.41 | 0% | $433.30 | 1% | $431.05 | 1% | $6.64 | 0% | $141.03 | 1% | $140.30 | 1% |
| B1: Equipment - National  | $0.00 | 0% | $10.22 | 0% | $0.00 | 0% | $0.00 | 0% | $3.33 | 0% | $0.00 | 0% |
| B2: Equipment - District  | $99.60 | 0% | $185.52 | 0% | $748.08 | 1% | $32.42 | 0% | $60.38 | 0% | $243.49 | 1% |
| **Capital - sub-total**   | $120.01 | 0% | $629.04 | 1% | $1,179.13 | 2% | $39.06 | 0% | $204.74 | 1% | $383.79 | 1% |
| **Recurrent**             |       |   |       |   |       |   |       |   |       |   |       |   |
| E1: Personnel & Per diems - HQ - International | $1,524.76 | 3% | $1,433.22 | 3% | $700.45 | 1% | $1,524.76 | 9% | $1,433.22 | 7% | $700.45 | 3% |
| E2: Personnel & Per diems - HQ - National   | $2,793.24 | 6% | $4,087.60 | 8% | $4,093.95 | 6% | $2,793.24 | 16% | $4,087.60 | 20% | $4,093.95 | 15% |
| E3: Personnel & Per diems - HQ - District    | $13,875.54 | 32% | $15,963.46 | 32% | $24,757.84 | 34% | $4,093.95 | 6% | $4,093.95 | 4% | $6,880.34 | 25% |
| E4: Personnel & Per diems - Field            | $12,805.91 | 32% | $15,367.09 | 31% | $15,367.09 | 23% | $3,920.18 | 23% | $3,920.18 | 23% | $4,704.21 | 17% |
| F1: Supplies                              | $132.70 | 0% | $47.09 | 0% | $49.29 | 0% | $54.80 | 0% | $19.45 | 0% | $20.35 | 0% |
| F2: HIVST kits                           | $10,898.74 | 25% | $9,640.27 | 25% | $19,407.31 | 29% | $4,500.88 | 25% | $3,981.17 | 19% | $8,014.69 | 30% |
| G: Vehicle operation, maintenance & transport | $16.20 | 0% | $50.34 | 0% | $145.96 | 0% | $126.43 | 0% | $39.06 | 0% | $204.74 | 1% |
| H: Building operation/maintenance          | $89.70 | 0% | $207.00 | 0% | $404.14 | 1% | $29.20 | 0% | $67.37 | 0% | $131.54 | 0% |
| K: Other recurrent costs                   | $189.41 | 0% | $592.80 | 1% | $1,210.96 | 2% | $78.22 | 0% | $244.81 | 1% | $500.10 | 2% |
| **Recurrent - sub-total**                  | $42,326.20 | 96% | $47,388.85 | 96% | $63,854.94 | 96% | $17,275.32 | 97% | $19,817.40 | 96% | $26,184.65 | 97% |
| **Total HIVST costs**                      | $43,879.81 | 96% | $49,451.50 | 96% | $66,647.67 | 96% | $17,869.55 | 97% | $20,577.31 | 96% | $27,123.61 | 97% |
| HIVST kits distributed                    | 3,739 | 0% | 3,867 | 0% | 6,598 | 0% | 2,023 | 0% | 1,130 | 0% | 2,667 |
| Average HIVST costs                      | $11.74 | 0% | $12.79 | 0% | $10.07 | 0% | $8.83 | 0% | $18.21 | 0% | $10.17 | 0% |