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MEASURING TECHNICAL EFFICIENCY OF THE PROVISION OF ANTIRETROVIRAL THERAPY AMONG PUBLIC FACILITIES IN BOTSWANA

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ACRONYMS

AIDS	Acquired Immunodeficiency Syndrome
ART	Antiretroviral Therapy
ARV	Antiretroviral drugs
AZT	Zidovudine
BWP	Botswana Pula
CD4	Cluster of Differentiation 4
CMS	Central Medical Store
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
DRS	Decreasing Returns to Scale
DTG	Dolutegravir
EFV	Efavirenz
FTC	Emtricitabine
FTE	Full-time Equivalent
GOB	Government of Botswana
HAART	Highly Active Antiretroviral Therapy
HFG	Health Finance and Governance
HIV	Human Immunodeficiency Virus
HR	Human Resources
IRS	Increasing Returns to Scale
LPV/r	Lopinavir/Ritonavir
MOH	Ministry of Health
NVP	Nevirapine
PPS	Probability Proportional to Size
RPR/VDRL	Rapid Plasma Reagin/Venereal Disease Research Laboratory
SD	Standard Deviation
TDF	Tenofovir
UNAIDS	Joint United Nations Programme on HIV/AIDS
USAID	United States Agency for International Development
VRS	Variable Returns to Scale
WHO	World Health Organization
3TC	Lamivudine

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EXECUTIVE SUMMARY

Botswana has made great strides in combating the HIV epidemic. Deaths due to AIDS have declined dramatically since 2005 (UNAIDS 2014; 2016) and the country is on its way to achieving its 90-90-90 targets (Gaolathe et al. 2016). As Botswana implements its ambitious Treat All Strategy and expands treatment to nearly 330,000 people living with HIV, the country will need to critically assess its efficient use of all available resources to sustain gains and continue progress towards an AIDS-free generation. To support the Ministry of Health with evidence regarding the efficiency of antiretroviral therapy (ART) service delivery, the USAID-funded Health Finance and Governance project estimated the overall and component-specific costs and utilization figures of adult outpatient ART care at Botswana's public health facilities.

The objective of this study was to analyze variations in the cost and efficiency of providing outpatient ART in public facilities in Botswana. Therefore, we applied an activity-based costing approach to collect data on the costs of delivering ART in a random sample of 120 facilities providing adult ART outpatient services in Botswana, including all 29 hospitals in the country and a representative sample of 73 clinics and 18 health posts. Clinical records for 2,241 adult patients on first line ART and 152 patients on second line were also sampled. Unit costs (per patient per year) are constructed for three main cost categories: antiretroviral drugs (ARVs), laboratory tests, and human resources. We implemented a Data Envelopment Analysis (DEA), a nonparametric technique, to estimate output-oriented efficiency scores and identify the most efficient facilities relative to others. The most efficient facilities are those that maximize outputs (number of patients receiving ART) given the number of inputs (ARVs, laboratory tests, number of full-time equivalent staff, and supplies). A regression analysis was applied to study factors driving differences in technical efficiency.

The costing analyses focus on cost per patient per year, stratified by level of care. Treatment costs vary widely between health posts and clinics. We estimate that in 2014, the national average ART unit cost is US$283 per patient per year (US$361 at health posts, US$309 at hospitals, and US$254 at clinics). ARVs represent 44 percent of the average total unit cost across all levels of care, and when stratifying, they are the largest component cost in hospitals and clinics, while human resources are the largest in health posts. ARV unit costs are the least variable, with a median of $125. Lab unit costs have intermediate variability among the three cost categories and fall between $60 and $90. Human resource costs are highly variable with a median of $55.[1]

The DEA results suggest that 69 percent of hospitals and 63 percent of clinics are technically efficient and operating on the efficiency frontier, relative to their peers at that level of the health system. No differences in technical efficiency were found among health posts. Comparing performance across different type of facilities, we find that hospitals have a higher proportion of technically efficient units compared to clinics; however, clinics have a slightly higher average efficiency score. DEA results indicate that inefficiencies in clinics appear to result from a high number of staff (both clinical and non-clinical) in relation to the volume of patients. The regression model shows that a higher average number of lab tests per patient and a higher proportion of clinical staff in facilities are associated with a significant decrease in efficiency scores. Given the large variations in human resource costs seen between health

[1] The 2014 exchange rate used to calculate the U.S. dollar amounts is 8.976 Botswana pula to US$1 (World Bank 2016).

posts and higher levels of care, a more rigorous planning process is needed to determine the distribution of clinical and non-clinical staff. One available option that suits this need is the WHO's Workload Indicators of Staffing Need (WISN) tool. Using four main types of data - number of staff trained for an activity, time needed to perform the activity, available staff time, and frequency of the activity - WISN can help identify staff maldistribution, excessive or deficient workloads, skill-mix imbalances and opportunities for task sharing (WHO 2016b).

Total costs are driven by the frequency and unit costs of each service delivery component. Adult patients had an average of three ambulatory visits per year and 4.4 lab tests across all levels of care, even among health posts and clinics relying on a well-functioning inter-facility network for test samples and results. Viral load and CD4 tests were most common, each with average annual utilization of 1.7 tests per patient in hospitals and slightly lower utilizations in clinics and health posts. Careful adherence to routine laboratory monitoring guidelines will help facilities maximize lab efficiency moving forward. Botswana might further reduce lab unit costs by adopting the 2016 WHO guidelines, which call for only annual viral load testing in stable patients and the cessation of CD4 testing where viral load monitoring is routinely available (WHO 2016a).

ARV drugs represent the main cost driver of ART care. There is little variation in overall or first line ARV unit costs between the three levels of care, but the same is not true for the doubly expensive second line drugs. ARVs account for nearly half of the total unit cost at clinics, yet the average costs of first and second line regimens are lower at clinics than at hospitals or health posts. Closer analysis of ART regimens, particularly second line regimens, is needed to discern what regimens are optimally efficient. As more patients initiate ART under "Treat All," more will inevitably require costly second line ARVs, making their efficient use critical to ART programming sustainability.

Patients are benefiting from less treatment variance; a significant proportion of patients (95 percent) receive fixed dose combinations, mainly emtricitabine+tenofovir+efavirenz (37 percent) and lamivudine+zidovudine (47 percent). The shift towards one daily pill not only simplifies treatment, but also reduces dosing errors, the number of hospitalizations and even the likelihood of developing HIV resistance. Nearly 95 percent of first line patients and 87 percent of second line patients comply with national and WHO ARV guidelines. Patients at all levels of care have almost a quarterly clinical check and receive on average at least one viral load and CD4 test per year, with hospital and clinic patients receiving closer to two of each.

Implementing differentiated models of care based on viral load outcomes can make care more patient-centric while reducing service delivery, and lab monitoring resource needs for stable, asymptomatic patients. Differentiated models of care consider patient status to determine their service needs in terms of type, location, provider, and frequency (WHO 2015). A multi-month prescriptions model, implemented nationally in Malawi, reduces annual clinic visits for those adult patients who have been adherent for six months or longer (CHAI 2016). Community-based ART groups or community health worker led groups can also reduce clinic visits and improve adherence. By implementing one or a combination of differentiated models of care, Botswana could lower annual patient costs and better allocate resources, allowing for improved health system efficiency.

Our findings suggest that HIV clinics in Botswana comply with national and international guidelines. Clinics achieve lower unit costs by providing services to many more patients, suggesting economies of scale. On average, clinics serve 400 patients per clinical FTE compared to 341 in hospitals and 77 in health posts. Treatment costs are higher in health posts, mainly attributable to more staff treating fewer patients, suggesting diminishing marginal returns as ART coverage expands into rural areas with low patient volumes.

The implementation of the ambitious Treat All Strategy in Botswana represents a stress test for the health system in accelerating access to treatment to nearly 330,000 people living with HIV. There is potential for Botswana to reduce unit costs and improve efficiency of ART services in three main areas: ARV procurement, routine lab monitoring, and clinical staffing. Botswana's facilities have room to increase outputs (number of patients on ART) under the current set of inputs (physical or financial) across all levels of care. Future reduction in ARV costs can be achieved through techniques including volume forecasting and price benchmarking. Following updated international guidelines on routine monitoring to reduce excessive testing will lower lab costs. Rebalancing of human resources through task sharing and task shifting can condense variance, reduce average costs, and ultimately improve efficiencies in the delivery of ART services in Botswana. Strengthening these areas and the overall health system will help Botswana continue its impressive progress towards an AIDS-free generation.

1. INTRODUCTION

1.1 Context and Background

With an adult HIV prevalence of 22.2 percent and approximately 330,000 of its citizens living with HIV (UNAIDS 2016), Botswana has made HIV/AIDS care a health priority. Botswana and its development partners have launched strong efforts to support programs for preventing mother-to-child transmission of HIV and providing treatment to those who need it. Botswana's efforts to treat and prevent HIV/AIDS have made significant progress – Botswana is already close to reaching the ambitious 90-90-90 UNAIDS targets (Gaolathe et al. 2016). The country has been successful in providing free universal access of antiretro-viral therapy (ART) to the HIV-affected population. Treatment programs have shown significant impact; from 2005 to 2013, HIV prevalence declined by 14 percent (WHO 2014), HIV incidence declined by 39 percent, and AIDS-related deaths declined by 59 percent (UNAIDS 2014). Despite widespread coverage of HIV programs, the country still ranks third in terms of global HIV prevalence. Mortality due to HIV has declined but the country is struggling to meet targets to reduce new HIV cases, and there has been a decline in adherence to treatment among the HIV-affected population (UNAIDS 2015).

Botswana's commitment to ensuring universal access to treatment sets it apart as a leader in HIV care and treatment. In 2016, the Government of Botswana (GOB) launched the ambitious "Treat All" Strategy, which will ensure that all patients testing HIV positive will start ART, regardless of their viral load or CD4 cell count. It is expected that this new strategy will increase the number of HIV patients receiving ART with a corresponding increase in the cost to the HIV/AIDS programs (Panel on ARV Guidelines for Adults 2016). Botswana will have 320,900 adults and 8,800 children receiving ART by the year 2020 with a total commodity cost of US$342.7 million over the period 2015-2020 (Dutta et al. 2015).

In response to these needs, there is a strong national commitment to increasing ownership of HIV prevention, care, and treatment efforts. With donor support decreasing and scope of treatment expanding through Treat All, it is critical that the GOB effectively use domestic resources to preserve the gains from HIV/AIDS programming while continuing progress toward national goals. These increasing resource needs require improvements in allocation of available resources and gains in efficient use of inputs, including reduction of waste and overall increase in health facility productivity.

Comprehensive national-level data on ART unit costs are a crucial component for resource planning efforts. A systematic review by Siapka et al. (2014) identified 34 ART unit cost studies, one of which included Botswana and four other countries (Menzies et al. 2011). Due to data validation issues, Menzies et al. were unable to include antiretroviral drugs (ARVs) in their total ART unit costs for Botswana, but did estimate the median non-ARV costs to be US$335 (in 2009 US$) for established adult patients. Comprehensive median ART costs (including ARVs) from the four other countries ranged from US$643 (in 2009-2011 US$) in Ethiopia to US$947 in Uganda, for an overall median of US$834. More recently, another multi-country study calculated comprehensive ART unit costs for Ethiopia, Malawi, Rwanda, South Africa, and Zambia (Tagar et al. 2014). Average ART unit costs ranged from US$136 in Malawi to US$682 in South Africa.

The previously described comprehensive ART unit costs included ARVs, routine lab testing, and human resource costs as components. ARVs are typically the largest cost component of ART programs in developing countries (Menzies et al. 2011; Sarti et al. 2012; Tagar et al. 2014), with consumption and buffer supply stocks accounting for nearly half of all ART costs (PEPFAR 2014). Fortunately, drug prices have gradually declined since 2000, to the point that countries sourcing generic first line ARVs can achieve costs as low as US$100 per patient per year (Médecins Sans Frontières 2016). Patterns observed in the Siapka et al. (2014) review reflect these declining prices although wide variations are also present, particularly in the sub-Saharan African countries.

Routine lab testing costs are influenced by the presence of appropriate facilities, frequency of testing, supply, personnel demands, and more, resulting in large variations in unit costs. The five-country Menzies et al. (2011) study, which included Botswana, estimated labs account for nearly 12 percent of total ART unit costs. An earlier study estimated labs account for 26 percent of total ART unit costs in South African referral hospitals (Rosen 2008). While there is a lack of recent, comprehensive data on lab costs specific to adult ART patients in Botswana, the *Models of Care* project, conducted from 2007-2011, estimated annual lab costs, including some HIV-relevant tests, to be US$97 per patient (GOB 2012b).

Human resource costs for ART vary according to cadre involvement, salary scales, and ratios of staff to patients. In the Tagar et al. (2014) study, South Africa had the highest human resource unit cost, US$334, by a wide margin, despite having a lower staff-to-patient ratio than two other countries, Rwanda and Ethiopia. While each country used similar numbers of doctors and nurses, their salaries were several times higher in South Africa, a reflection of differing economic circumstances. Rwanda and Ethiopia also made heavy use of low cost community health workers, enabling them to add staff without much salary burden. Menzies et al. (2011) excluded Botswana from estimations of human resource costs for ART, but reported 9.2 percent of total ART costs were for personnel in the other countries examined.

In addition to costs, countries must also consider efficiency of their ART services. Inefficient use of existing health resources leads to substantial amounts of wastage, acting as a barrier to new efforts to expanding coverage and improving service quality (WHO 2010). Data Envelopment Analysis (DEA) of national HIV/AIDS programs in 151 countries found that, on average, countries achieved only half of their potential program outputs (given their inputs), compared to their peers (Zeng et al. 2012). Another recent DEA of ART programs at all levels of care in Zambia, Uganda, and Kenya drew similar conclusions, stating that wide variations and low average efficiency scores (59 percent in Zambia, 50 percent in Uganda, 51 percent in Kenya) result in many fewer patients receiving ART than possible given the existing resources (Di Giorgio et al. 2016). To our knowledge, no study has specifically examined the efficiency of ART programs in Botswana, but a DEA of general health services in district and primary hospitals in Botswana found that 13 were operating at technically inefficient levels, and could have combined to provide for nearly 120 thousand additional outpatient visits and 50 thousand inpatient days (Tlotlego et al. 2010).

Botswana has undergone a political, administrative, and fiscal decentralization with the District Health Management Teams now responsible for delivering services. It is expected that services will improve as the teams have more adequate funds and technical experience at their disposal (Somanje et al. 2012). This study generates new knowledge, identifying factors that can lead to improvements in the efficient allocation and use of ART resources, thereby enabling long-term sustainable domestic funding. This is critical as Botswana expands its HIV response to ensure improvements in the delivery of ART services are made in a sustainable manner and based on local solutions.

1.2 Study Objectives

The GOB has reached impressive ART coverage levels and financing commitments to HIV; however, the shift toward a test-and-treat strategy requires consideration of the sustainability of Botswana's HIV response. With this in mind, the GOB has demonstrated a keen interest in better understanding the factors that influence efficiency at the facility level in order to inform future HIV programming.

The purpose of this study is to provide the GOB with key indicators on the efficiency of ART provision in Botswana at the facility and district levels. Specific objectives are to:

1. Estimate the inputs (e.g., unit costs, volume of ARVs, laboratory tests, and labor of doctors and nurses) and outputs (e.g., number of services provided to ART patients) of adult outpatient ART provision at the facility and district levels
2. Assign relative efficiency scores to each facility, demonstrating the variation in efficiency across facilities and identifying which facilities have scope for improving efficiency
3. Identify factors enabling high efficiency scores at some facilities, and barriers to efficient provision at others
4. Provide general recommendations for improving efficiency to program management and stakeholders

2. METHODOLOGY

For the costing component of the study, HFG used a "probability proportional to size" sampling methodology, which created a sample of 120 public facilities, including 29 hospitals, 73 clinics, and 18 health posts. In addition, 20 patient records were randomly selected from each facility, for a total of 2,400 patients. Primary data collection was supplemented with secondary data from publicly available sources and the literature. Data cover the study period of January 1 through December 31, 2014. The HFG team first used these data to calculate the unit cost of providing ART outpatient services per adult patient per year and measure other inputs such as the labor of doctors and nurses (in terms of full-time equivalents, FTEs) and outputs (such as number of adult ART patients provided with care). The team then conducted a DEA, applying the inputs and outputs collected as part of the costing component of the study to evaluate efficiency at each facility and compare efficiency among facilities of similar scale. This study analyzes cost and efficiency of ART at the point of service delivery. As Clift et al. point out in their *Landscape Study of the Cost, Impact, and Efficiency of Above Service Delivery Activities in HIV and Other Global Health Programs* (2016), many supporting activities are conducted above the point of service delivery, such as district-level program management, monitoring and implementation, and procurement and supply-chain services. Assessing the cost of these services above the point of service delivery was outside the scope of this study. It is also important to note that this study was conducted from a health service provider perspective and aimed to identify cost drivers and potential interventions to increase efficiency and save money for the health sector. Patient outcomes and the quality of services provided were beyond the scope of this study. This chapter provides additional detail on the steps taken to complete this study.

2.1 Sampling Design

The target population for the survey was all public hospitals, clinics, and health posts in Botswana that offer ART services. The objective was to select a representative probability sample of hospitals, clinics, and health posts. A sample of patients was selected from each facility in the sample.

2.1.1 Selection of Facilities

Twenty-nine hospitals, 210 clinics, and 45 health posts were eligible for sample selection. In view of the small number of hospitals with a large population of patients, the study team decided to include all the hospitals in the sample with certainty. This means estimates for hospital characteristics have no sampling error.

The study team decided to select 73 clinics from the population of 210 clinics. The clinics were sorted by district. It was decided to use probability proportional to size (PPS) sampling where size is the number of patients in each facility rather than using an equal probability selection, which does not take into account the size of the facility.

The sample was selected using PPS systematic sampling. The size is the number of patients in a clinic. The probability of selecting a clinic say "i" in the sample is

$$73\ \frac{X_i}{X}$$

where X_i is the number of patients in facility i and X is the total number of facilities in the entire district. Under this method, if the size of a facility is very large, the probability of selection will turn out to be greater than 1.00. All facilities that had a probability of selection greater than 1.0 were selected with certainty. Out of 73 facilities, 21 facilities were selected with certainty. The remaining 52 were selected with PPS out of the remaining 189 facilities. Systematic sampling ensures representation of all the districts in the sample.

In a similar way, probability proportional to size systematic sampling was also used to select 18 health posts in the sample.

The base sampling weight for each responding facility is the inverse of the probability of selection.

2.1.2 Selection of Patients within a Facility

Twenty adult patient records were sampled from each facility. To be eligible for inclusion in the study, the sampled record had to meet the selection criteria outlined below. If a record was selected that did not meet these criteria, then it was returned and a new record was sampled in its place. Patient record selection criteria:

- Patient must have been registered in this clinic before January 1, 2014
- Patient must have been alive on January 1, 2014
- Patient must have started ART treatment before January 1, 2014
- Patient must be 15 years or older as of January 1, 2014

In facilities where an electronic patient record database was available, the data collector worked with the facility staff to randomly sample clinical records. Where only paper records were available, the data collector worked with the medical records staff to randomly pull files from the shelves.

In some facilities, the records for live patients were stored separately from those for the deceased. When this was the case, data collectors were instructed to randomly pull one deceased patient record per facility and sample the remaining 19 records from the living patients.

2.1.3 Ethics

This research protocol received ethical review approval through both Abt Associates' Institutional Review Board and the Botswana Ministry of Health's (MOH's) Health Research and Development Committee ethical review boards.

Patient confidentiality was maintained and no identifying information was ever collected during the patient record review, captured in data collection tools or interview notes, or included in the results presentation or final report. Costing data for the purpose of our study were facility-specific and unrelated to any particular patient.

2.2 Data Collection and Entry

Data collection took place in two phases, the first from November 16, 2015 to December 12, 2015 and the second from April 11, 2016 to May 6, 2016.

The HFG team trained sixteen local data collectors to administer the questionnaire forms and visit the facilities in pairs. The study team developed two data collection forms: 1) the facility form collected facility-level data, including data on ART visits, human resources, and the stocks of ARVs and other supplies; 2) the patient record form collected information around number of visits over the study period, ARV regimens and dates of switch to second or third line regimens, number of lab tests performed, and presence of opportunistic infections.

Between the two phases, the study team reviewed surveys from the first round of data collection, identifying data gaps and areas that required further follow-up. Any issues with data collection were brought to the attention of the data collectors, and, during the second phase of data collection, the data collectors filled critical gaps.

Data were entered from the paper forms into FluidSurvey, a structured data entry template between May and June 2016. The data were then cleaned and prepared for the costing analysis. The study team used Microsoft Excel and Stata 12.0 for the data analysis. HFG stored the data electronically, on password-protected laptops.

Secondary data from central offices were compiled for the analysis. The Central Medical Store (CMS) provided procurement prices of ARVs and of clinic and lab supplies. The MOH provided salary grades for public sector employees, the number of ART patients, and other facility variables in December 2014. Additional data from secondary sources, for example, on lab test costs and inflation and exchange rates for Botswana, were also compiled.

2.3 Costing

2.3.1 Overall Approach

Each unit cost is composed of four service delivery components: (1) ARVs, (2) human resources, (3) laboratory tests, and (4) HIV clinic supplies. This section provides an overview of the data cleaning and estimation methods used for the utilization of HIV and health services and each service delivery component. For more detail on the costing methods used, please see Annex A.

Data were cleaned and analyzed in Excel unless noted otherwise. Prices were adjusted to 2014 Botswana pula (BWP) using Gross Domestic Product deflators from the International Monetary Fund's Global Economic Outlook Database for April 2016 and currency exchange rates from the World Bank.

2.3.2 Summary of Methods

Utilization of HIV and Health Services: We calculated several variables summarizing the utilization of HIV and other health services at the surveyed facilities based on information collected in the patient and facility forms, and MOH (2014) data on the number of patients on ART nationally. We used these variables to complete the estimate of the unit cost. The variables estimated were:

- **Number of adult ART patients at each facility:** Since facility data on the total number of patients receiving treatment at HIV clinics were often missing, incomplete, or included aggregated adult and pediatric patients, we turned instead to centrally reported data on the number of patients on ART in December 2014 (MOH 2014). These data included the percentage of patients on ART who are children. To estimate the total number of adult ART patients per facility, we excluded pediatric patients in the relevant ART site from the total number of ART patients. Patients were specified as first or second line patients based on their ARV regimens described in the ARV drug section (the sample did not include any third line patients).

- **Number of HIV clinic visits:** As with the number of patients, many facilities lacked accurate data on the overall number visits. However, our forms collected information about each HIV clinic visit in 2014 for the sampled patients. From these data, we calculated the average number of visits per patient at each site. To estimate the total number of outpatient ART-related visits, we multiplied these estimates of average number of visits per year by the number of total ART patients, number of first line patients, and number of second line patients (see above).
- **Allocation ratio of HIV clinic to total facility costs:** The questionnaire collected the number of visits at each outpatient clinic in each facility. We condensed outpatient clinics into six groups: HIV clinic, general outpatient, maternal and child health, pediatrics, voluntary counseling and testing for HIV, and dentistry. All facilities had at least HIV and general outpatient services, while some had all six clinical services. Additionally, some facilities had inpatient wards, while others did not. We estimated a ratio using the number of clinical services (outpatient and inpatient) as the denominator, and one (HIV outpatient clinic for ART) as the numerator. We used this ratio to allocate non-clinical staff costs to HIV clinics.

ARV Drugs: We estimated the cost of ARVs per adult patient per facility. We prepared data on the volume of each drug (in terms of number of tablets) and multiplied by prices (per drug per tablet).

Data on the prices of the ARV drugs mainly came from the CMS, where ARVs are centrally procured for all public facilities. However, CMS data did not include prices for some drugs reported in the exact same molecule formulation and prices of the same drug or drug combinations varies by formulation.[2] In these cases, we used additional data sources, including ARV price data from Médecins Sans Frontières (2012; 2014) and the Botswana HIV & AIDS Treatment Guidelines (GOB 2012a) to estimate prices per tablet for those drugs listed in the questionnaires but not the CMS data.

We excluded ARVs in liquid units or drugs with pediatric formulations from the unit cost estimation in order to exclude drugs intended for pediatric patients. We also excluded drugs that that did not appear to be in the regular ARV regimen for first, second, or third line.

Lab Tests: To estimate lab test costs, we compiled lab utilization data from the patient records and multiplied it by secondary data on the lab costs – costs which included the cost of human resources and supplies.

Human Resources: For the human resources costs, we first calculated the number of clinical and non-clinical FTEs for each cadre per facility, both in the overall facility and specifically in the HIV clinic. Reported human resource costs are based only on the time cadres spend in the HIV clinics and the allocated non-clinical human resource time described earlier. Using salary data provided by GOB, we calculated the average salary per cadre per facility, which we multiplied by the number of FTEs per cadre per HIV clinic.

[2] A "formulation" is different from a "dosage." The formulation is the mg amount per tablet of a drug. The dosage is the mg amount that needs to be taken daily. For example, Aluvia may be available in a 125mg or 250mg amount per tablet (two formulations).

Cost of HIV Supplies: Since the facilities had varying qualities of inventory management and record keeping, many facilities did not have specific information on the supplies disbursed to HIV clinics. To overcome this limitation, we calculated the average per patient per year supply costs for the two HIV clinics with the most complete information, and used this value to impute HIV clinic supply costs at all facilities. This method is grounded in the assumptions that all facilities receive their clinical supplies from CMS for roughly the same prices, and that care for each patient consumes a similar number of supplies across facilities.

2.4 DEA Conceptual Framework and Model Specifications

Building upon the work of Farrell (1957), DEA was first developed by Charnes et al. (1978) and extended by Banker et al. (1984). DEA is a frontier methodology that has been widely used for measuring efficiency of health care organizations (Cooper et al. 2000). It is a non-parametric approach that uses linear programming techniques to estimate the relative efficiency in a group of Decision Making Units (DMUs), in which all members are fairly homogenous and use an identical set of inputs to produce a variety of identical outputs. It allows multiple inputs and outputs. In this study, the HIV clinic inside each health facility represents a DMU.

In DEA, the DMU is considered technically efficient when the DEA score equals 1 and all slacks are 0 (Worthington 2004). A slack is how much a particular input could be decreased or a particular output increased for a DMU to reach the efficiency frontier or for one that is already on the frontier to reach a better point on that frontier. The efficient DMUs are located on the efficiency frontier and those that are inefficient operate at points in the interior of the frontier.

We use variable returns to scale (VRS) in this analysis and an output-oriented model where, with their current level of inputs, the HIV clinics are expected to maximize the number of patients they are treating. For more detail on the DEA and the specifications of our analysis, see Annex B.

As noted earlier, the set of DMUs should be as homogeneous as possible in terms of the inputs they use and the type of outputs they produce. To that effect, we estimated three different DEA models for the different types of facilities providing ART services in our sample: hospitals, clinics, and health posts.

2.4.1 Regression Analysis

The prevalent method in the literature to find the determinants of efficiency gaps among DMUs is by using Tobit regression analysis because the efficiency scores are censored at the maximum value of the efficiency scores (Ji and Lee 2010). The Tobit regression analysis uses the efficiency scores as the dependent variables along with a set of independent variables on facility activity level and characteristics.

2.4.2 Summary of Methods

For DEA, inputs can be measured as counts by type (e.g., nursing hours, bed days, supply of drugs) or they can be monetized (real or standardized dollars assigned to each unit) (Hussey et al. 2009). They are respectively referred to as physical inputs or financial inputs. The way in which inputs are measured may influence the way the results are used. It is also possible to mix the two types of inputs. In modeling the efficiency scores, we used five input and two output variables. The input variables for each facility were: number of FTE clinical staff, number of FTE non-clinical staff, total costs of laboratory tests, total ARV costs and total clinical supply costs. The output variables included: the number of patients on first line ART treatment and the number of patients on second line ART treatment. Previous analyses have used similar output measures (Zeng et al. 2014). Data were obtained for 29 hospitals, 73 clinics, and 18 health posts.

For the Tobit model, we used a set of facility characteristics: HIV prevalence in the facility district (%), availability of a laboratory inside the facility (Yes/No), external support from partners (Yes/No), number of lab tests per patient, ratio of clinical and non-clinical staff per 100 patients, proportion of HIV clinic clinical staff out of the total facility clinical staff. All costs in this study are expressed in 2014 BWP.

2.5 Limitations

Some facilities included in this study contained pediatric wards and did not disaggregate pediatric and adult patient data. In those cases, pediatric data were excluded from the unit cost calculations as this study only looks at adult patients. We were not able to estimate unit costs for training staff in ART because the combination of primary and secondary data together was insufficient to establish strong estimates. We were not able to estimate overhead costs for renovation, construction or other investments, utilities, travel, or building use. Most prices and salaries were from the central level or secondary sources as facilities did not generally know or store this information. Facilities did not generally have comprehensive utilization or ART patient data. As a result, we relied on centrally compiled data. Additionally, the HIV clinic supply stock data were generally of poor quality.

It is important to note that the DEA benchmarks health facilities only against the best performers in the sample. It assumes that if a health facility can produce a certain level of output utilizing specific input levels, another health facility of equal scale should be capable of doing the same. DEA determines relative efficiency and not absolute efficiency. Therefore, having a representative sample in a DEA analysis – as is the case in our study – is important for the generalizability of the results.

3. RESULTS

3.1 Descriptive Statistics

Descriptive statistics (Table 1) show that on average total inputs (human resource or financial inputs) are highest in hospitals, followed by clinics and health posts. The number of patients treated (both first and second line) also follow that ranking. Please note that the unit of analysis here is the HIV clinic inside a particular type of facility: hospitals, clinics, and health posts and that when we refer to those types of facilities, it means the HIV clinic inside the facility. The following sections break down the cost estimates for each of the input variables.

Table 1: Mean of Selected Input and Output Variables by Facility Type

Variables	Hospitals	Clinics	Health Posts
Sample size	29	73	18
ART patients	2431	1326	102
Output Variables			
First line patients	2175	1243	97
Second line patients	250	78	5
Input Variables			
Total ARV costs (BWP)	2,976,590	1,513,571	116,721
Total lab tests costs (BWP)	1,861,687	896,605	64,831
Total clinical supplies costs (BWP)	46,497	25,372	1,953
FTE clinical staff	7.1	3.3	1.3
FTE non-clinical staff	18.5	2.0	1.0
Total staff costs (BWP)	1,709,015	467,005	197,509

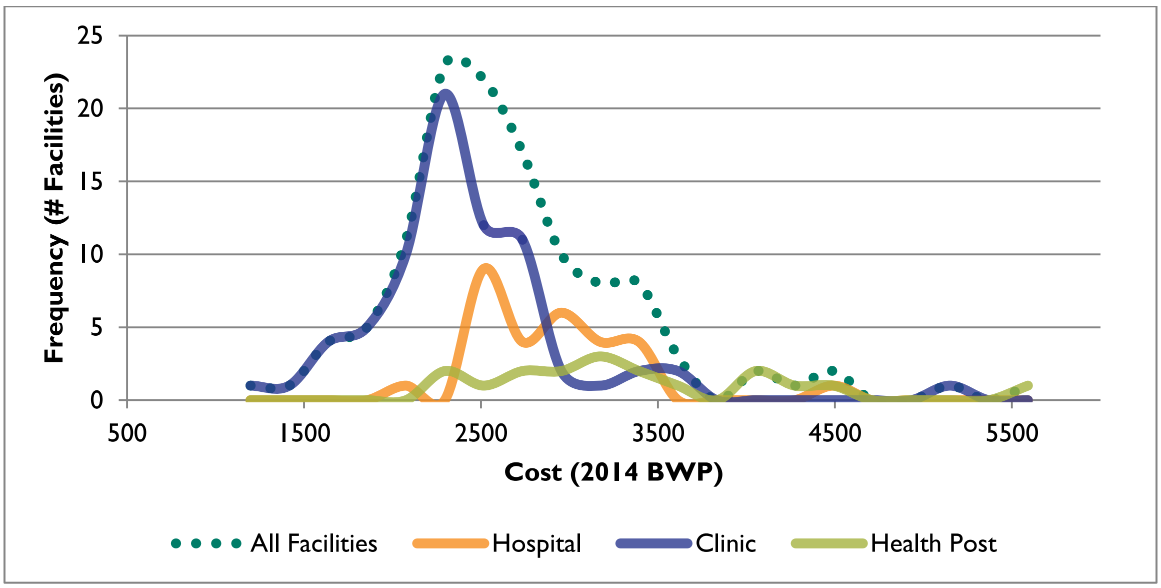
3.2 Estimates of Adult ART Costs

This section presents the results of costs estimates among adults receiving ambulatory care in public hospitals (referral and district), clinics, and health posts. Annex C presents unit cost results by district. All values are in 2014 BWP[3].

3.2.1 Mean Overall Unit Costs

Figures 1 and 2 show overall and category cost distributions by relating the number of facilities to the ranges of unit cost estimates. Figure 1 presents the overall cost distribution as well as the cost distribution for hospitals, clinics, and health posts. It shows that most (63 percent) of facilities have unit costs between BWP 2,000 and BWP 3,000. It also shows that there are several facilities with unit costs that exceed this range significantly: the facility with the highest unit cost has an estimated unit cost of BWP 5,589. Of the six facilities with estimated unit costs greater than BWP 4,000, four are health posts, one is a clinic, and one is a hospital.

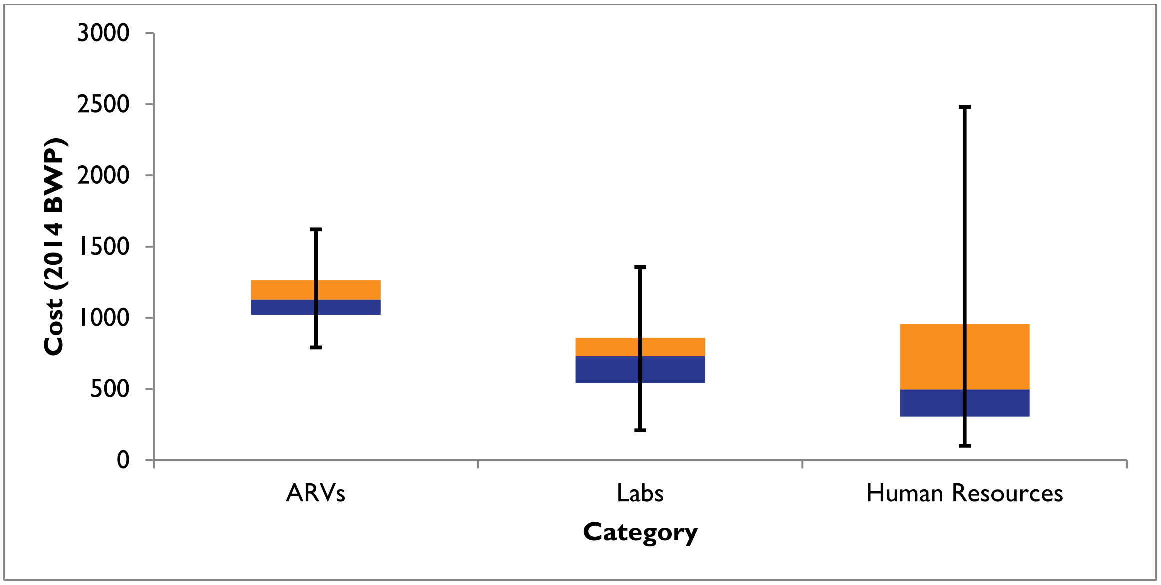
Figure 1: Total Unit Costs (BWP) by Facility Type



[3] The 2014 exchange rate 8.976 Botswana pula to US$1can be used to convert to US$ (World Bank 2016).

Figure 2 shows the distribution of unit costs for the ARV, lab, and human resource categories. ARV unit costs were least variable, clustering tightly around a median of BWP 1,128. Lab costs had intermediate variability and generally fell between BWP 541 and 859. Human resource costs were highly variable, with a wide distribution of costs well above the BWP 496 median.

Figure 2: Distribution of Category Costs (BWP)



Note: Bottom box edge represents first quartile, middle line represents median, and upper box edge represents third quartile. For clarity of data presentation, human resources exclude two facilities considered outliers (z-score > 3 SDs from the mean). Kgwatlheng Clinic has a human resource unit cost of BWP 3,018 and Kumakwane Health Post has a human resource unit cost of BWP 3,936.

Table 2 presents average unit costs, and their standard deviations (SD), by cost category and level of care. Average total unit costs are higher in health posts and clinics than in hospitals. This difference is primarily due to variation in human resource costs, the greatest source of variation in costs across levels of care. Human resource costs in health posts are on average BWP 680 higher than in hospitals and BWP 996 higher than in clinics. Lab costs were highest at hospitals, followed by clinics and health posts. In contrast, average ARV costs per patient are relatively consistent across the three levels of care (range of BWP 132). Average supply costs are identical given the method for estimating this cost center (please see methods section for more detail). Table 2 also shows the relative weight of each category on the total unit cost. Human resources are the largest category in health posts, while ARVs are largest in hospitals and clinics.

Table 2: Mean (SD) Unit Costs (BWP) by Level of Care

Category	Hospital (n=29)		Clinics (n=73)		Health Post (n=19)		All Facilities (n=120)	
	Unit Cost (BWP)	% Total	Unit Cost (BWP)	% Total	Unit Cost (BWP)	% Total	Unit Cost (BWP)	% Total
ARVs	1231 (181)	44	1099 (179)	48	1151 (114)	35	1138 (180)	45
Labs	750 (176)	27	698 (230)	30	619 (215)	19	699 (219)	27
Human Resources	794 (397)	28	478 (429)	21	1474 (849)	45	704 (617)	28
Supplies	19 (.0)	0.7	19 (.0)	0.8	19 (.0)	0.6	19 (.0)	0.7
Total	2794 (476)	100	2294 (546)	100	3262 (847)	100	2560 (688)	100

Note: Mean values for the ARV drug unit costs sum total ARV drugs (both first and second line) and divide by the number of facilities in a level of care; they are not weighted by estimates of the number of first and second line patients.

3.2.2 ARV Drug Unit Costs

Table 3 presents the average first and second line ARV costs per patient by level of care. Results indicate that unit costs for first line drugs do not vary much by level of care. Costs of second line drugs, used by 6.3 percent of sampled patients, vary more by level of care, with higher average per patient costs at hospitals and health posts than at clinics. Second line drug costs also show more variation within each facility type, seen in the higher standard deviations for second line drug costs.

Table 3: Mean (SD) Costs (BWP) of First and Second Line Drug Regimens by Level of Care

	# First Line Patients	# Second Line Patients	First Line ARV Costs (BWP)	Second Line ARV Costs* (BWP)
Hospitals (29)	522	57	1,114 (139)	2,374 (993)
Clinics (73)	1,376	78	1,043 (148)	1,997 (904)
Health posts (18)	343	17	1,094 (90)	2,307 (641)
All facilities (120)	2241	152	1,068 (141)	2,135 (898)

*Nine hospitals, 23 clinics, and nine health posts were excluded from second line ARV cost estimates because no patients sampled from these facilities were on second line ARVs in 2014.

A significant proportion of patients (95 percent) receive fixed dose combinations, mainly emtricitabine+tenofovir+efavirenz and lamivudine+zidovudine, as seen in Table 4.

Table 4: Frequency of ARV Drug Combinations

First Line ARVs	# of Patients	% of Patients
Tenofovir/Emtricitabine/Efavirenz - TDF/FTC/EFV	831	37%
Efavirenz – EFV + Zidovudine/Lamivudine - AZT/3TC	533	24%
Nevirapine – NVP + Zidovudine/Lamivudine - AZT/3TC	530	23%
Nevirapine – NVP + Tenofovir/Emtricitabine - TDF/FTC	246	11%
Other first line ARVs	101	5%
Total	2241	100%
Second Line ARVs	**# of Patients**	**% of Patients**
Lopinavir/Ritonavir - LPV/r + Tenofovir/Emtricitabine - TDF/FTC	119	78%
Lopinavir/Ritonavir - LPV/r + Zidovudine/Lamivudine - AZT/3TC	14	9%
Other second line ARVs	19	13%
Total	152	100%

3.2.3 Lab Tests Unit Costs

Adult ART patients in Botswana average 4-5 lab tests per patient per year across all levels of care (Table 5). The fact that health posts (at 4.11 tests per year), which do not have lab facilities, are not far behind hospitals (at 4.52 tests per year) or clinics (at 4.41 tests per year) indicates that the cross-facility lab system is effective. Viral load, CD4, and Pap smear tests reflect this pattern. The largest difference between hospitals and health posts is for viral load testing. Interestingly, blood tests (full blood count and its component tests) follow the opposite pattern, with health posts and clinics averaging at 0.6 tests per patient (about 2 in 3 patients receiving a test per year), while hospitals average 0.5 tests per patient (about 1 in 2 patients receiving a test per year). Testing for co-morbidities is relatively infrequent across all levels of care.

Costs per patient for lab tests mirror their utilization. Costs per patient are highest at hospitals, second highest at clinics, and lowest at health posts. The test with the highest average cost per patient is for viral load tests at hospitals. CD4 tests have lower average costs and less variation across levels of care than viral load tests. After CD4 and viral load tests, renal function tests have the next highest average costs. Among the different types of blood tests, the full blood count test has the highest average cost per patient at clinics. Full blood count tests are also the most costly when comparing different blood tests.

Table 5: Mean (SD) Utilization and Costs (BWP) of ART Lab Tests by Level of Care

		Utilization per Patient			Costs per Patient (BWP)		
		Hospitals (29)	Clinics (73)	Health posts (18)	Hospitals (29)	Clinics (73)	Health posts (18)
CD4		1.70 (0.38)	1.59 (0.45)	1.49 (0.44)	104 (23)	97 (27)	91 (27)
Viral load		1.67 (0.39)	1.52 (0.53)	1.41 (0.48)	594 (140)	541 (188)	502 (171)
Blood tests	Full blood count	0.21 (0.25)	0.24 (0.25)	0.21 (0.22)	7 (8)	7 (7)	6 (7)
	White blood cell*	0.10 (0.18)	0.13 (0.22)	0.13 (0.21)	4 (7)	5 (9)	5 (9)
	Red blood cell*	0.13 (0.21)	0.14 (0.24)	0.15 (0.20)	3 (4)	3 (5)	3 (4)
	Platelets*	0.08 (0.12)	0.13 (0.22)	0.13 (0.20)	2 (3)	4 (6)	4 (6)
Lactate		0.01 (0.02)	0 (0.01)	0 (0.01)	0.5 (1.49)	0.1 (1)	0.1 (1)
Liver function test		0.11 (0.18)	0.14 (0.26)	0.09 (0.17)	6 (9)	7 (13)	5 (9)
Renal function test		0.39 (0.31)	0.47 (0.38)	0.42 (0.45)	22 (17)	26 (21)	23 (25)
Blood chemistry		0.04 (0.08)	0.02 (0.05)	0.06 (0.13)	3 (6)	2 (3)	4 (9)
Pregnancy		0 (0.02)	0	0	0.1 (1)	0	0
Rheumatoid factor		0 (0.01)	0	0	0.1 (0.4)	0	0
Hepatitis B		0	0 (0.01)	0	0	0.1 (1)	0
Hepatitis C		0	0 (0.01)	0	0	0.1 (1)	0
Tuberculosis skin		0 (0.02)	0	0	0.3 (2)	0	0
Tuberculosis sputum		0	0 (0.01)	0	0	0.2 (1	0
RPR/VDRL		0.02 (0.04)	0.01 (0.02)	0.01 (0.03)	0.4 (1)	0.3 (1)	0.2 (1)
Average lab utilization		4.52	4.41	4.11	750	696	645

*White blood cell, red blood cell, and platelets lab tests are all components of the full blood count test.

3.2.4 Human Resource Unit Costs

Table 6 presents human resource costs per patient by level of care. It first presents costs for the three cadre groups most involved in ART service provision: doctors, nurses and midwives, and pharmacy staff. Nurses and midwives account for the largest per patient human resource cost at all levels of care. They are most costly at health posts (BWP 909), where their workload is distributed among fewer patients on average than at hospitals and clinics. The column "total clinical costs" adds the costs of these three cadres together with the costs of other cadres who contribute to the clinical aspects of ART services provision. Findings again show that per patient clinical human resource costs are highest and most variable at health posts (unit cost BWP 1,064, SD BWP 762) compared to hospitals (unit cost BWP 434, SD BWP 254) and clinics (unit cost BWP 407, SD BWP 408).

The column "total non-clinical costs" in Table 6 presents the costs per patient for management and maintenance of HIV clinics by administrators, cleaners, security and other staff. These costs include costs of non-clinical staff who work in the HIV clinic and a percentage of costs for non-clinical staff working in the entire health facility. Non-clinical human resource costs are highest at health posts (BWP 410 per patient), again driven by relatively small numbers of ART patients. Non-clinical costs are second highest at hospitals (BWP 360), which require more staff including high-level administrators. Clinics, by comparison, have a very low non-clinical human resource cost at BWP 71 per patient, reflecting a much lower ratio of staff to patients.

The last column in Table 6, "total human resource unit costs," adds together total clinical and total non-clinical human resource costs per patient. While the clinical costs at hospitals and clinics are very similar (BWP 434 and 407, respectively), the total human resource unit cost at hospitals is much higher than at clinics (BWP 793 and 478). This is driven by the large difference in non-clinical costs seen at each level, mentioned above. Health posts have the highest total human resource unit cost at BWP 1,474, due to the high costs of nurses and midwives. However, health posts' high standard deviation of BWP 849 implies wide variation in the human resource unit costs of individual health posts.

Table 6: Mean (SD) Human Resources Unit Costs (BWP) by Level of Care

	Doctors	Nurses and Midwives	Pharmacy Staff*	Total Clinical Costs** (BWP)	Total Non-clinical Costs (BWP)	Total Human Resource Unit Costs (BWP)
Hospitals (29)	87	288	31	434	360	794
	(136)	(185)	(61)	(254)	(199)	(397)
Clinics (73)	120	202	43	407	71	478
	(336)	(205)	(76)	(408)	(66)	(429)
Health posts (18)	94	909	0	1064	410	1474
	(135)	(754)	(.0)	(762)	(216)	(849)
All facilities (120)	108	329	34	512	192	704
	(276)	(424)	(68)	(507)	(205)	(617)

**Pharmacy staff includes pharmacists and pharmacy technicians.*

***"Total clinical costs" include the doctors, nurses and midwives, pharmacy staff, and unlisted cadres such as assistants, laboratory technicians, and counselors.*

3.2.5 HIV Supplies

Prices for HIV clinic supplies are based on supply prices from the Botswana CMS, which distributes supplies to all public facilities. Prices from the UNICEF Supply Catalogue are also used for items not included in the CMS supply report provided. Unit costs are based on supply records from two facilities with the most complete HIV clinic supplies data, Kanye Main Clinic (BWP 7.52 per patient) and Xhosa Clinic (BWP 30.74 per patient) for an average of BWP 19.13 per patient. Supplies include bandages, needles, syringes, gloves, and alcohol.

3.3 Data Envelopment Analysis

3.3.1 Technical Efficiency Comparison Across Facility Types[4]

An output-oriented model is used in this study, where efficiency consists of maximizing output (number of patients on ART) given a set of inputs (physical or financial). When comparing performance across different types of facilities (Table 7) a greater percentage of hospitals (69 percent) are technically efficient, as compared to 63 percent among clinics. In the aggregate, however, clinics have a slightly higher average efficiency score.

The average slacks for the four inputs represented are higher for inefficient units compared to efficient units and in general higher in clinics than in other types of facilities. The following sections provide additional breakdown by facility type.

Table 7: Average Efficiency Scores and Slacks by Type of Facility

	Hospitals		Clinics		Health Posts	
	Technically efficient	**Technically inefficient**	**Technically efficient**	**Technically efficient**	**Technically inefficient**	**Technically efficient**
Number of DMUs	20 (69%)	9	46 (63%)	27	18 (100%)	0
Average efficiency score	1	0.982	1	0.985	1	NA
Average slack for ARV costs (BWP)	44,985	344,623	203,529	82,271	2,880	NA
Average slack for lab costs (BWP)	103,955	366,941	118,727	343,804	3,429	NA
Average slack for FTE clinical staff	0.36	1.87	0.98	2.21	0.08	NA
Average slack for FTE non-clinical staff	0.62	1.61	0.18	0.88	0.27	NA

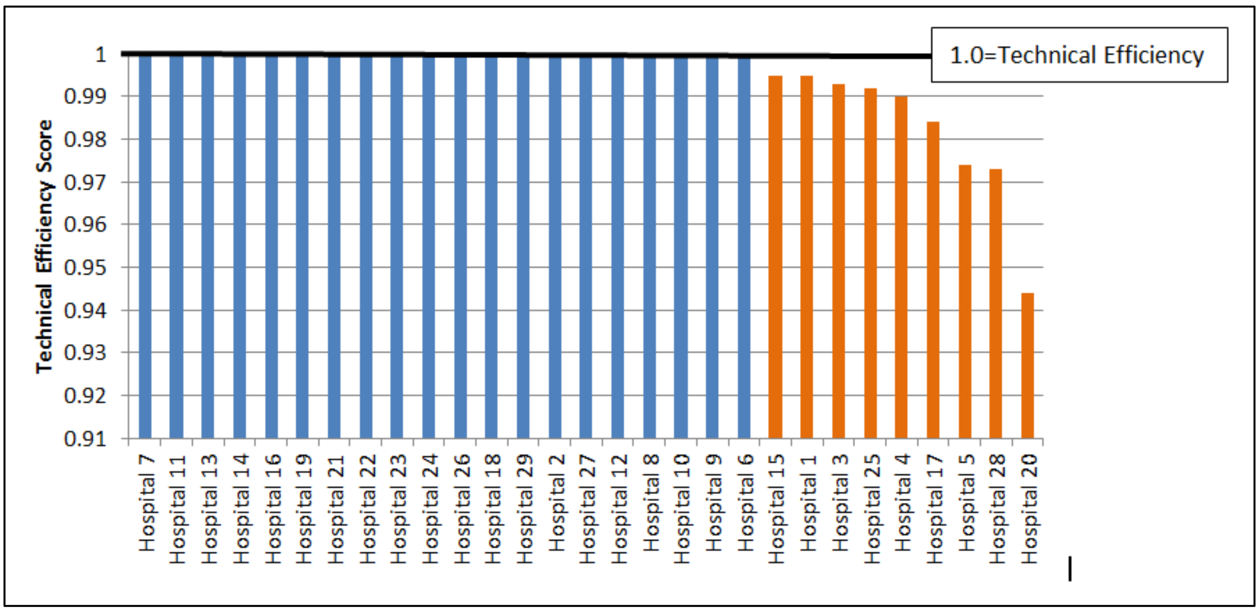
[4] This section presents technical efficiency results; see Annex D for scale efficiency results. Disclosure of the facility names is available upon request.

3.3.2 Measuring Technical Efficiency Across Hospitals

In the sample of 29 hospitals, 20 (69 percent) are technically efficient (Figure 3). The remaining nine (31percent) are technically inefficient, which means that compared to their peers they fail to maximize their output given their current level of inputs. To reach the efficiency frontier, each inefficient hospital should increase all its outputs by a percentage of (100- score*100). For example, Hospital 3 still has room to increase both the number of first line and second line patients with its current level of inputs. Such an increase in output would bring Hospital 3 to the efficiency frontier, but because the hospital also displays input slacks, it could reach a better point on that frontier by decreasing ARV costs as well as total lab costs (refer to Table D1 in Annex D).

Among the inefficient hospitals, 78 percent have slacks in total costs of ARVs, 89 percent in costs of lab tests, 56 percent in costs of FTE clinical staff, and 33 percent in costs of FTE non-clinical staff. The relatively high proportion of hospitals with ARV and lab cost slacks can signal possible wastage in those inputs and the need to monitor them closely.

Figure 3: Technical Efficiency Scores Across Hospitals

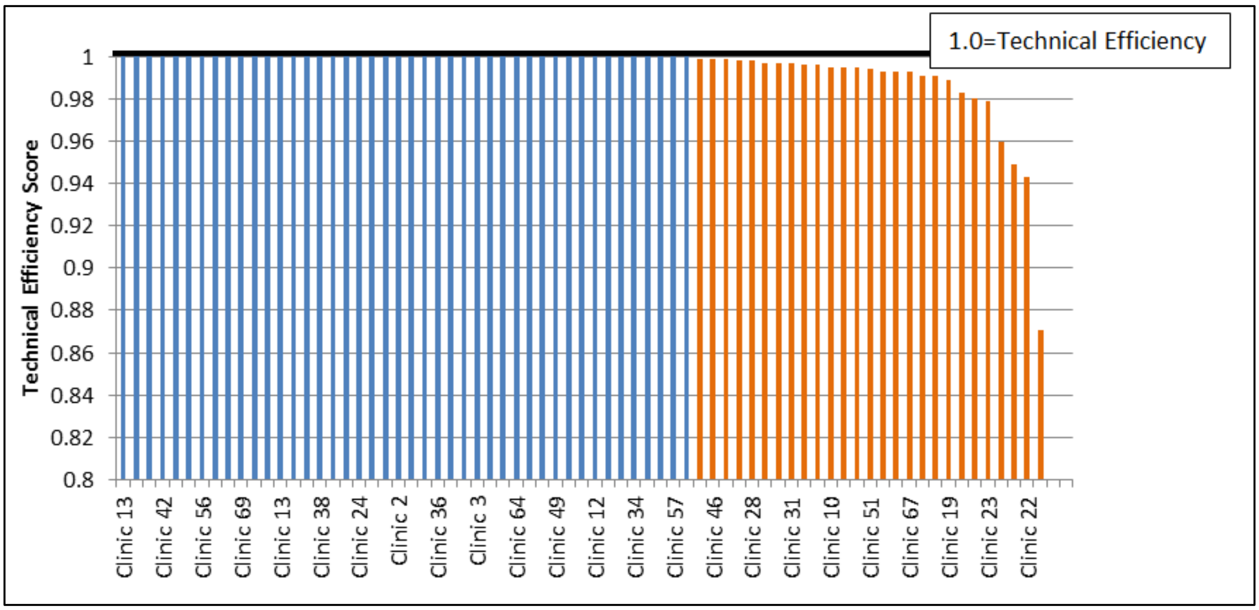


3.3.3 Measuring Technical Efficiency Across Clinics

Forty-six clinics (63 percent) are technically efficient and 27 (37 percent) have lower than optimal efficiency scores (Figure 4). The results show that the 27 technically inefficient clinics could, on average, increase the number of ART patients they are treating to become efficient. Four of those technically inefficient clinics also have output slacks for second line patients, meaning that after increasing both the number of first and second line patients by the same proportion to reach the efficiency frontier, they still have the capacity to treat more second line patients to reach a better point on that frontier. Therefore, as more patients initiate ART under the Treat All Strategy, there is ample room to efficiently accommodate patients requiring first or second line regimens.

Clinics showing lower efficiency scores also have inputs slacks: 63 percent have slacks in total ARV costs, 89 percent in total lab tests costs, 96 percent in number of FTE clinical staff, and 59 percent in number of FTE non-clinical staff.

Figure 4: Technical Efficiency Scores Across Clinics



3.3.4 Measuring Technical Efficiency Across Health Posts

All 18 health posts have comparable technical efficiency scores. In simple terms, compared to each other and considering the level of inputs they are using, no particular health post is performing significantly better or worse than its peers. As seen in the descriptive statistics (Section 3.1), the health posts already function with low levels of inputs, and the results seem to indicate that they are all comparable in terms of using inputs to produce outputs. However five health posts do have input slacks, meaning they could achieve better scores on the efficiency frontier and save money by decreasing some specific inputs. Figure 5 shows the efficiency score, slacks, and scale efficiency of Health Post 12 as an example. For efficiency scores and slacks for the full sample of health posts, see Table D3 in Annex D.

Figure 5: Efficiency Scores and Input/Output Slacks for Health Post 12

Health Post	Technical Efficiency Score	Input Slacks					Output Slacks		Scale Efficiency: Returns to Scale
		ARV Total Costs (BWP)	Lab Tests Total Costs (BWP)	Clinical Supplies Total Costs (BWP)	FTE Clinical Staff	FTE Non-Clinical Staff	# First Line Patients	# Second Line Patients	
Health Post 12	1	7,130	3,535		0.33	0.77	0		0

Health Post 12 could achieve savings and decrease its ARV costs by BWP 7,130, its lab testing costs by BWP 3,535, its number of FTE clinical staff by 0.33, and its number of FTE non-clinical staff by 0.77 and still be able to treat the number of patients it is currently treating.

3.3.5 Regression Analysis Results

Table 8 reports on the regression analysis of the technical efficiency scores for clinics only. We did not run a regression for health posts as all of them were comparable in their efficiency scores. We ran regression for hospitals but the small sample size made the Tobit model not fit the data well (Prob > chi2 for the Likelihood ratio Chi2 test were not significant at 5 percent), so those results are not reported.

For clinics (sample size of 73), we regressed the technical efficiency scores on a list of covariates that could potentially affect those scores. Regression covariates were taken from facility characteristics collected in our questionnaires.

The model shows that having a laboratory on site, receiving external support (technical or financial), and the HIV prevalence at the district level do not have any significant effect on the technical efficiency scores.

A higher average number of lab tests per patient is associated with a statistically significant decrease in technical efficiency scores, using a significance level of 5 percent. A high ratio of number of clinical staff per 100 patients is associated with significant increase in the technical efficiency score while a high ratio of non-clinical staff per 100 patients is associated with significant decrease in efficiency scores.

A higher proportion of clinical staff dedicated to the HIV clinic among the total clinical staff of the facility is associated with a significant decrease in efficiency scores. This finding indicates that HIV clinics in facilities where ART represents a larger share of the facilities' clinical staff time are associated with lower technical efficiency scores. Thus, while having more clinical staff versus non-clinical staff in the HIV clinic can contribute to higher efficiency scores, facilities where clinical staff are more concentrated in the HIV clinic (versus other clinics in the facility) are associated with a lower efficiency score.

Table 8: Regression Analysis Results for Clinics

Variables	Efficiency Coefficient
Constant	1.07 (0.027)***
Laboratory (Yes/No)	-0.014 (0.012)
External support (Yes/No)	0.004 (0.008)
District HIV prevalence (%)	-0.0003 (0.001)
Average number of lab tests per patient	-0.006 (0.002)**
Ratio of number of FTE clinical staff per 100 patients	0.056 (0.012)***
Ratio of number of FTE non-clinical staff per 100 patients	-0.088 (0.020)***
Proportion of total facility FTE clinical staff working in the ART clinic	-0.106 (0.034)***
LR chi2 (7)	24.45
Prob > chi2	0.0009
No. observations	73
Uncensored observations (Efficiency score <1)	27
Right-censored observations (Efficiency score=1)	46

Standard errors are reported in parentheses

, ** and * represent significance at 10%, 5%, and 1% respectively*

Understanding the table: The variables in the left column are the covariates (or X variables) that were regressed onto the technical efficiency scores (Y variable). The results table can be read as follows: As the average number of lab tests per patient increases, the technical efficiency score decreases by an average of -0.006. In general, for each one unit increase in X, there is a decrease of the efficiency coefficient's value in Y.

4. DISCUSSION AND CONCLUSION

Our study shows that ARVs are the largest cost category when averaging across all facilities, while lab and human resource costs are nearly even. This is in line with findings from other developing countries where ARVs, lab testing, and human resources are the main cost drivers of outpatient ART services (Menzies et al. 2011; Sarti et al. 2012; Tagar et al. 2014). However, when stratifying by level of care, our analysis reveals that different cost categories have more varied impacts on total unit costs.

Health posts have the highest average total unit cost among the three levels of care, as well as the largest variation in total unit costs. The total unit cost of care at health posts is largely (45 percent) driven by the high unit cost of human resources, in relation to a lower volume of patients. Health post HIV clinics attend to an average of only 102 unique patients per year. By comparison, providers in hospitals and clinics attend to an annual average of 2,438 and 1,329 unique patients, respectively. Therefore, although hospitals and clinics have a higher average number of clinical FTEs in their HIV clinics, including more doctors, the distribution of the clinics' costs over more patients results in much lower human resource unit costs than observed at health posts. The high treatment costs at health posts suggest diminishing marginal returns as ART coverage expands into harder to reach rural areas with low patient volume. Although health posts have high unit costs for treatment, health posts have comparable efficiency scores.

Despite having the highest unit costs for ARVs and labs, hospitals have only the second highest total unit cost. Hospital patients receive an average of 4.5 lab tests annually, including 1.7 of both CD4 tests and viral load tests per person. These patients come closer to receiving the levels of laboratory-supported HIV monitoring recommended in Botswana's 2012 guidelines than their counterparts at clinics and health posts, without incurring substantially higher costs. This balancing appears to be achieved through less frequent testing for comorbidities than clinic and health post patients receive. Approximately 69 percent of hospitals are technically efficient, relative to each other, and are located on the efficiency frontier. Nine hospitals are technically inefficient and have room for improvement. The results indicate that relatively high ARV and lab costs may be driving these technical inefficiencies, therefore closer adherence to clinical guidelines may be needed to reduce inefficiencies through excessive testing.

Clinics have the lowest total unit cost among the three levels of care. While ARVs account for nearly half of the total unit cost at clinics, the average unit costs of both first and second line treatment regimens are lower at clinics than at hospitals or health posts. Clinics achieve very low unit costs for human resources by providing services to many patients, suggesting economies of scale. On average, clinics serve 400 patients per clinical FTE compared to 341 in hospitals and 77 in health posts. In terms of non-clinical FTEs, there is a stark contrast between clinics and hospitals – clinics employ an average of two non-clinical FTEs compared to 18.5 at hospitals. Although clinics have the lowest unit costs, they are the least technically efficient relative to one another; 63 percent of clinics are technically efficient. Twenty-six clinics have room for improvement and can decrease some of their inputs while still remaining on the efficiency frontier. For technically inefficient clinics, the inefficiencies appear to result from a high number of FTE staff (both clinical and non-clinical) in relation to the volume of patients attended (outputs). These findings raise questions about staff planning and distribution at different levels of care.

Findings at the district level are in line with those observed when stratifying by level of care. Unit cost at the district level is highly sensitive to the number of health posts sampled per district. Gantsi district, with four facilities, has the highest average total unit cost, mostly due to high human resource costs. Two facilities in the district are health posts, each with a relatively high number of FTEs serving a small number of patients. Serowe/Palapye district has the most facilities sampled (10 clinics and two hospitals) and has an overall average total unit cost of BWP 2,160, which is close to the average across all facilities. Finally, six of the seven facilities surveyed in the Kweneng West district are health posts. Accordingly, the average human resource cost in this district is nearly BWP 1,000, reflecting our findings of high human resource costs at health posts. Full results of the unit cost analysis by district are included in Annex C.

Overall, we find that ART services in 2014 meet the standards of care established in Botswana's 2012 guidelines. There is low variation in ARV regimens and nearly 95 percent of first line patients and 87 percent of second line patients comply with national and World Health Organization (WHO) ARV guidelines. On average, patients receive adequate routine lab testing at all three levels of care, suggesting the inter-facility network for test samples and results functions as intended. Patients at all levels of care receive a clinical checkup on an almost quarterly basis, typically with a doctor or nurse capable of prescribing ARVs. Botswana's high standards of care compare favorably to ART services in the United States and Europe, and find the country well positioned to handle the Treat All Strategy and its challenges.

Providing ARVs for an estimated 330,000 people will be Botswana's largest challenge under the Treat All Strategy. Based on our costing and DEA results, evidence from other countries, current WHO guidelines, and in consideration of the newly issued Handbook of the Botswana 2016 Integrated HIV Clinical *Care Guidelines*, there is potential for Botswana to reduce unit costs and improve efficiency of ART services in three main areas: ARV procurement, routine lab monitoring, and clinical staffing.

While most newly diagnosed and initiated patients will require first line regimens, lifelong ART for all patients will also inevitably lead to many new patients on second line ARVs which can be up to three times as expensive (Médecins Sans Frontières 2016). Lessons from other countries can help Botswana reduce these ARV costs by optimizing its procurement and supply chain management system. South Africa once faced high ARV costs, but reduced overall ARV drug costs by 53 percent by implementing ARV procurement process reforms, allowing for scale-up. The government utilized price benchmarking against prices in the WHO Global Price Reporting Mechanism, setting ceilings during the bidding process (UNAIDS 2013). Swaziland also used price benchmarking, taking prices from the Clinton Health Access Initiative (CHAI) to set ceilings that, along with other interventions, ultimately lowered drug costs by 33 percent from 2009 to 2012 (UNAIDS 2013). Use of third-party negotiators with drug suppliers and annual revision of tenders are also methods of increasing bidding competition and achieving the lowest possible drug prices each year (UNAIDS 2013; Wirtz et al. 2009). Better monitoring and quantification of drug needs can also help lower ARV costs by improving accuracy during the forecasting phase of procurement (Ripin et al. 2014). Swaziland used the forecasting tool CHAI-Chart to better plan its ARV procurement and reduce waste (UNAIDS 2013). Finally, acquiring drugs from generic companies, rather than originators, can help reduce prices (Wirz et al. 2009). Keeping prices low is critical, as even a small reduction in costs per patient per year could result in massive savings, given the large volume of patients in Botswana.

Under Botswana's 2016 ART guidelines, patients failing first line treatment will switch to a second line regimen based on drug resistance testing and consultation with an HIV specialist. The WHO recommends a fixed-dose combination of TDF+FTC+EFV, currently the most common regimen in Botswana, as the preferred option for first line patients and AZT+3TC+ATV/r as a preferred option for second line patients. However, Botswana's 2016 ARV guidelines instead recommend all new first line patients to initiate a regimen of Dolutegravir (DTG) paired with TDF and 3TC (GOB 2016). Limited evidence suggests DTG regimens can achieve better viral load and CD4 outcomes with less treatment discontinuation than EFV regimens, but evidence of DTG safety for pregnant or tuberculosis co-infected patients is still pending (WHO 2016a). The new DTG regimen also moves away from the single pill, fixed dose combination of TDF+FTC+EFV. Evidence shows one daily combination-pill for ARV reduces dosing errors and likelihood of developing drug resistance, while also improving treatment adherence, effectiveness, and patient satisfaction (Sax et al. 2012; Bangsberg et al. 2010; Hodder et al. 2010). Botswana should continue to monitor WHO recommendations as new evidence on the safety and efficacy of DTG becomes available.

Botswana's 2016 guidelines call for less frequent lab testing than the 2012 guidelines, which on average we observed patients were meeting. We also found that patients at some facilities underwent lab testing well beyond the guidelines, in turn skewing the average numbers of viral load and CD4 tests upwards and masking the number of patients receiving insufficient testing. Facilities at all levels of care can reduce lab test unit costs and improve efficiency by strictly adhering to the new 2016 guidelines, which eliminate excessive testing. Viral load testing, the most expensive lab of routine HIV monitoring, should only occur 3 and 12 months after ART initiation during a patient's first year, then every 6 months thereafter, assuming they are virally suppressed. CD4 testing should occur at initiation, 3 months, 12 months, and every 12 months thereafter. Botswana might further reduce lab unit costs by adopting the 2016 WHO guidelines, which call for only annual viral load testing in stable patients and the cessation of CD4 testing where viral load monitoring is routinely available (WHO 2016a). For example, using the aforementioned strategy of ending CD4 testing for virally suppressed patients, South Africa expects to reduce CD4 testing costs by an estimated 51 percent, US$ 68 million, from 2013 to 2017 (Stevens and Ford 2014).

Given the large variations in human resource costs seen between health posts and higher levels of care, a more rigorous planning process is needed to determine the distribution of clinical and non-clinical staff. One available option that suits this need is the WHO's Workload Indicators of Staffing Need (WISN) tool. Using four main types of data - number of staff trained for an activity, time needed to perform the activity, available staff time, and frequency of the activity - WISN can help identify staff maldistribution, excessive or deficient workloads, skill-mix imbalances, opportunities for task shifting, and more (WHO 2016b). Namibia and Uganda are two of several African countries that recently assessed national human resources for health using WISN. Findings in each country varied but generally revealed shortages of doctors and pharmacists relative to workload, inequitable distribution of nurses (McQuide 2013), and, in the case of Uganda, a surplus of nursing assistants (Namaganda 2015). These findings prompted the national ministries of health to begin developing new strategies for human resource planning, distribution, task shifting, and even the inclusion of WISN as an official policy consideration in Namibia. Utilization of WISN across Botswana should be considered; a 2014 pilot implementation of the WISN tool in the Kweneng East district found that some cadres regularly engage in tasks outside their scope of work, including administrative tasks by clinical staff (WHO 2016b). Such instances are a misuse of valuable staff time and represent opportunities for improvement through better staff distribution and a clearer delineation of roles.

Task sharing is another mechanism that some countries are implementing to optimize human resource costs and improve efficiency. Evidence from Ethiopia supports task sharing for ART services; no significant differences in patient outcomes were found between physician and non-physician clinician-lead ART care from 2008 to 2010 (Johns et al. 2014), and patients seen by nurses or health officers reported higher satisfaction with their ART visits than patients seen by physicians in 2012 (Asfaw et al. 2014). In Botswana, the Lay Counselor cadre created in 2001 has helped start patients on ART and lessened burdens on more skilled staff (Ledikwe et al. 2013). While task shifting and task sharing bears their own costs in the form of training and supervision, the lay counselors have been found effective in their roles and satisfactory to patients in Botswana. Task sharing from doctors to nurses and nurses to lay counselors (or similar low-skill cadres), if done with adequate attention to quality, may help reduce unit costs, particularly at health posts, without negatively impacting patient outcomes.

Implementing differentiated models of care approach is another option for improving health system efficiency. Differentiated models of care consider patient status to determine their service needs in terms of type, location, provider, and frequency (WHO 2015). In Malawi, stable adult patients who have been adherent on first line ART six months or longer and without side effects are eligible for differential models of care (CHAI 2016). One model, available nationally, is for multi-month prescriptions, in which stable patients reduce their annual number of clinic visits by receiving three or more months of ARVs at a time. Other models involve fewer full service visits with high level cadres, and community-based ART groups, where a rotating member picks up ARVs for the entire group. An estimated 69 percent of patients are on the multi-month prescriptions model, and annual costs of care for stable patients on any model are 10 percent lower than non-model patients. The 2016 WHO guidelines on viral load monitoring also create models of care, with stable patients receiving only annual testing after their first year on ART. Sustainability of HIV care in Africa requires viral-load-informed differentiated models of care. Patients with suppressed viral load would require less frequent monitoring, freeing providers to focus on patients with unsuppressed viral load, promoting adherence and allowing timely switching to second-line regimens (Phillips et al. 2015). Utilizing point-of-care viral load testing technology can also help make care more patient-centric by enabling more timely results delivery and improved adherence support (Cogswell et al. 2015). By adopting these or similar models of care based on viral load status and targeting the areas of ARV dispensing, service delivery, or lab monitoring, Botswana could more accurately allocate resources based on patient needs, leading to reduced costs and improved efficiency of care, particularly for stable, asymptomatic patients.

Finally, we provide recommendations for future studies. Supplementing our results with qualitative interviews would provide perspective on management-related issues, not revealed in the quantitative data, that impact facility efficiency. Further, although facilities overall are following guidelines in terms of drug regimens and number of tests, a more detailed analysis is needed to observe whether those facilities deemed technically inefficient are also following clinical guidelines. Readily available and uniformly kept records will streamline future efforts by the MOH and partners to monitor unit costs and efficiency at the facility level. The MOH should improve the data quality by keeping complete and accurate records on patients, utilization, lab test, drugs, non-drug supplies, and human resources. Although this study employs a health systems perspective and not a societal one, studying costs to the patient outside of the facility would provide a more comprehensive picture of the of current costs of ART from both the health system and household perspective.

The implementation of the ambitious Treat All Strategy in Botswana represents a stress test for the health system in accelerating access to treatment to nearly 330,000 people living with HIV. Smart health system solutions coupled with innovative service scale-up strategies are critical to sustainably achieving this goal. Our findings demonstrate there is room to increase outputs (number of patients on ART) under the current set of inputs (physical or financial) across all levels of care. Cost savings and efficiency gains in the areas of ARV procurement, routine lab testing, and task shifting among human resources will play an important role in scaling up services. Strengthening these areas and the overall health system will help Botswana continue its impressive progress towards an AIDS-free generation.

ANNEX A: SUPPLEMENTAL METHODOLOGY FOR UNIT COST ANALYSIS

Antiretroviral Drugs Cost Category

Overall approach

We estimated the cost of ARVs per adult patient per facility. We prepared data on the volume of each drug (in terms of number of tablets) and multiplied by prices (per drug per tablet).

Data on ARV prices came mainly from the CMS, where ARVs are centrally procured for all public facilities. However, CMS data did not include prices for many drugs reported by facilities in exactly the same molecular formulation – and prices of the same drug or drug combinations vary by formulation.[5] In these cases, we used additional data sources, including ARV price data from Médecins Sans Frontières (2012; 2014) and the Botswana HIV and AIDS treatment guidelines (GOB 2012a), to estimate prices per tablet for those drugs reported but not in the CMS data (GOB 2012a).

We excluded ARVs in liquid units or drugs with pediatric formulations from the unit cost estimation in order to exclude drugs intended for pediatric patients. We also excluded drugs (Fluconazole, Paracetamol, Cotrimoxazole, Nalidixic Acid, and Dapsone) that that did not appear to be in the regular ARV regimen for first, second, or third line.

Unit Costs for ARV Drugs

Data were gathered on the type of drug, unit (e.g., bottle or box), number of tablets per unit, and the stock for each drug at each facility (specifically: balance in January, amount received, balance in December, and amount not sent to the HIV clinic, for 2014). Patient-specific data were collected on the drug type, classified by line (first, second, or third), "daily dose," and number of days on drug during the study period. For patients switching from one line to another, the patient data also included the date of the prescription change

Volume of ARVs (# tablets) for each ARV drug: We calculated the quantity of bottles (or other unit) by adding the balance of bottles in January and the quantity of bottles received during 2014, and then subtracting the balance of bottles in December and the quantity of bottles not sent to the HIV clinic in 2014. If data were missing on either the balance in January or December, the quantity of bottles received during 2014 was used as the total quantity of bottles at that facility for the year. When the quantity of bottles received during 2014 was missing, we imputed the volume for a given drug by multiplying the mean annual number of tablets per drug per patient from the patient data we collected for that facility by the number of first or second line patients at the facility. Finally, we multiplied the number of bottles by the number of tablets per bottle to estimate the volume of tablets per drug per facility per year. When the number of tablets per bottle was missing, we used data from other facilities on the same drug, applying the most commonly used number.

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[5] A "formulation" is different from a "dosage." The formulation is the mg amount per tablet of a drug. The dosage is the mg amount that needs to be taken daily. For example, Aluvia may be available in a 125mg or 250mg amount per tablet (two formulations).

In some cases, enumerator comments indicated that the survey reported a start or end balance that was not January 2014 and December 2014. To avoid underestimating the stock used during the study period, we calculated the exact number of days for which there was stock balance information and divided it by the volume of bottles that were reported stocked during this period. We then multiplied this estimate by 365 to project the actual volume for the entire year.

Removing duplicates: In some cases, facilities listed a drug twice. When the drugs listed had the exact same name and formulation, we included the drug entry with the higher quantity and excluded the other. However, if there were any differences in the name listed or if we had imputed the formulation for one or both of the entries, we included both drug entries.

Estimating missing formulations: In some cases, the facility-level data did not specify the molecular formulation for a drug. For these drugs, we used information in the treatment guidelines (GOB 2012a). When the Guidelines included only one formulation for the drug in question, we used that formulation. When the Guidelines included multiple formulations per drug, we used the median or mean, on a case-by-case basis given other contextual information.

Classifying patients by drug line and related data exclusions: For patients whose records included both first and second line drugs: we classified patients as second line when there were data on the date for switching their prescription or when the data specified a date during the first half of 2014. We classified patients as first line patients when they specified the date of switching their prescription during the second half of 2014. We also classified as second line patients whose record had no information on the date of switch but listed both first and second line drugs during the study period. This approach helped ensure that we did not underestimate costs by underestimating the number of second line patients relative to first line patients. (Our dataset did not include any patients on third line treatment.) In line with this classification, we excluded first line drugs for second line patients who switched prior to 2014; second line drugs for patients classified as first line patients.

Estimation: To estimate patient's volume of tablets for each ARV drug, we multiplied the number of days in the study period during which the patient used the drug by the number of tablets the patient used per day.

However, the patient data were unclear or incomplete on:

1. Exactly which drug was referred to (i.e., its molecular formulation) so that we could align those drugs with the correct price
2. The number of days per year a patient used a given drug
3. The number of tablets the patient took per day of usage (i.e., dosage)

1. Specific drug formulation

We treated the patient data on "daily dosage" as the drug formulation when it provided a milligram amount because we believe that the enumerators interpreted this column to be a formulation. For some records, the milligram amount for a drug was listed but appeared to be incorrect, for example, because the drug was not actually available in this specified milligram amount. In these cases, we estimated the formulation and daily dosage based on dosage information from the treatment guidelines and on pills available in the market. In the case where "daily dosage" did not provide a milligram amount, we assumed that the formulations for each drug were the same as for the set of pre-listed formulations in the questionnaires on facility drug stock, which were developed from other surveys from the region.

2. The number of days per year a patient used a given drug

When data on the number of days a patient used a given drug were missing, we assumed the patient had used the drug each day of the year (i.e., 365 days).

3. Dosage/number of tablets the patient took per day of usage

In some cases, daily dose specified "two tablets bi-daily." We interpreted this phrase to mean two tablets per day, except for Aluvia when we interpreted this dosage to mean two tablets twice a day. The rationale for treating Aluvia differently was that Annex 5 of the treatment guidelines specifies that the recommended daily dose for Aluvia was four pills a day (250mg each), but to interpret "two tablets bi-daily" as four pills per day for any other drug would be assuming an irrationally high number of pills. When no other dosage information (number of tablets per day) was provided, we estimated it using Annex 5 of the treatment guidelines (GOB 2012a).

Removing duplicates: Any case when a patient or facility record showed multiple entries of the same drug, we applied the same protocol (see above).

Laboratory Tests Cost Category

Overall approach: We collected data at the facility and patient level on labs, but we only estimated lab test costs per patient per facility from using patient-level data because some facilities with labs would have run tests for facilities without labs. Given our goal of estimating per patient costs, using facility-level data would have overestimated costs for patients at facilities with labs, and underestimated them at facilities without labs. To estimate lab test costs, we compiled utilization data for patients and multiplied it by secondary data on the lab costs – which included the cost of human resources and supplies.

Utilization data: Our questionnaire asked for utilization of 18 labs specifically, and also included space to list additional lab tests that the ART patients received in 2014. We observed that some of the tests patients received were sub-tests of larger, all-encompassing tests. For example, hemoglobin is a sub-test of a Red Blood Cell (RBC) test, which is a sub-test of a Complete Blood Count (CBC). Because we could not find the costs of every lab and sub-lab test, we met with a physician and used a Project Inform document (Project Inform 2011) to categorize component labs ("B") into their respective all-encompassing lab tests ("A") (Table A1). One exception was for complete, or full, blood count tests. Because its component tests are often done separately, we treated these components as independent tests. Thus, we list these tests (white blood cell, red blood cell, and platelets tests) in column A.

Table A1: Lab Test Classification

Lab Tests (A)	Component Tests (B)*	Source for cost data
CD4	CD4 count, CD4%, CD8, CD8%, CD8 absolute, CD4/CD8 ratio, CD4, T-lymphocyte CD4/CD8 ratio	(GOB 2012b)
Complete blood count/Full blood count**		(GOB 2012b)
White blood cells	Basophil %, Neutrophil %, Lymphocytes (LYMP), Neutrophils (NEUT)	Adjusted from (Theranos 2016)
Red blood cells	Hematocrit, Mean Corpuscular (MCS), mean corpuscular hemoglobin, Reticulocytes, Mean Corpuscular Volume (MCV), hemoglobin, Mean Corpuscular Hemoglobin (MCH) concentration	Adjusted from (Theranos 2016)
Platelets	mean platelet volume	Adjusted from (Theranos 2016)

Lab Tests (A)	Component Tests (B)*	Source for cost data
Blood chemistry	Cholesterol, glucose, baseline chemistry, calcium, triglycerides, Gamma Glutamyl Transpeptidase, lipid profile, potassium, random glucose, Chemistry, glucose/total cholesterol, sodium, Low density lipoprotein (LDL) cholesterol	(GOB 2012b)
Liver function test	Alanine trans (ALT), Aspartate trans (AST), Albumin, protein, total bilirubin, Albumin (ALB), total protein, aspartate amino transferase, Alinine Amino Tranferase Serum, albumin serum, total protein serum	(GOB 2012b)
Renal function test	Creatinine Jaffe gen 2 comp, Creatinine, Creatinine Serum, Sodium, Chloride (Cl-), potassium (K+), potassium indirect, sodium indirect, uric acid, kidney/renal function test, Urea, Urea/Electrolyte, Urea/Electrolyte and creatinine clearance (U/E+CREAT), Creatinine Clearance	Adjusted from (Theranos 2016)
Viral load		(GOB 2012b)
Lactate test		Adjusted from (Theranos 2016)
Pap smear	Cervical cancer	(Lince-Deroche et al. 2015)
PPD skin test		(Steffen et al. 2013
Chest X-ray		(Samandari et al. 2011)
Sputum (for tuberculosis)		(Samandari et al. 2011)
RPR/VDRL		Adjusted from (Theranos 2016)
Rheumatoid factor		Adjusted from (Theranos 2016)
Pregnancy		Adjusted from (Theranos 2016)
Hepatitis C	Hepatitis C Virus (HCV)	Adjusted from (Theranos 2016)
Hepatitis B	Hepatitis B Surface Antibody (AHBS)	Adjusted from (Theranos 2016)

**Tests listed in column B are only those examples of component tests that appeared in the survey; they are not a comprehensive list.*

To avoid double-counting, we applied the following rules to these data to estimate lab test utilization per ART patient:

1. If the patient record lists only one of the component tests, we use the number of tests per year for this test as the utilization estimate.
2. If more than one type of component test, all falling under the same larger lab test, were listed and each component test only took place once, then we counted it as one test. However, if more than one of any type of component test of a larger test took place, then we used the highest frequency as the lab utilization.
3. If the patient record lists one all-encompassing lab tests and one component test, then we will treat as two tests.

Finally, we estimated the average utilization per lab per patient per facility, and multiplied by the number of ART patients at each facility.

When a patient record listed a lab test name but left the number of tests blank, we imputed a value using the average number of tests per patient for that specific lab by facility level. We also excluded entries for which we did not have lab costs (Rapid HIV Testing), which we could not identify ("ESR"), or which are not actually lab tests (Nevirapine chemistry and Cervical LEEP).

Lab test prices: We relied on secondary data for lab costs. We contacted key informants in Botswana and conducted an online search to identify existing studies that estimated the full cost of each lab listed in column A (Table A1). Using this approach, we found estimates from Botswana for seven of 19 lab tests (GOB 2012b; Samandari et al. 2011), one from South Africa (Lince-Deroche et al. 2015), and one from Brazil (Steffen et al. 2013).

To estimate costs for the remaining 10 tests, we accessed lab test prices from the American company, Theranos, and compared its prices for the liver function test with the unit cost for the liver function test from GOB (2012b). Since the GOB estimate was 90 percent of the Theranos price, we used 90 percent of Theranos prices for the missing lab test costs. This approach allowed us to retain survey data for all labs listed and thus account for variation in utilization across facilities in the unit cost estimates. It assumes that the relative values of the lab test prices are similar in the United States and Botswana.

Human Resources Cost Category

Classifying cadres: Clinical cadres included doctors, nurses, midwives, health care assistants, counselors, pharmacists, and other staff involved with the health and well-being of patients. Non-clinical cadres included facility administrators, cleaners, drivers, security, and other staff involved in non-health care activities at and around facilities. Personnel originally recorded as belonging to "other" cadres were condensed into existing or new categories as appropriate. We calculated total FTE per cadre based on a **standard of 2,080 hours per year.**

FTEs Formula: #FTEs = [(#cadre working per day)* (#hours per day)*(#days per week)*(#weeks per year)]/2080

We estimated the number of days per week worked based on the number of days that the facility or HIV clinic was open per week. However, we capped the number of days per week worked at five, under the assumption that individual workers would not generally exceed that number.

FTEs Cost Formula: Cadre FTEs cost = (#FTEs) * (Average cadre salary)

Salary data: Salary data for 2014 was provided by the GOB. Where salary information for a specific cadre was missing, we used the average salary across all facilities for that cadre instead, based on consistency of intra-cadre salaries observed in the data.

HIV Clinic Supplies Cost Category

Cleaning data on supply volume: Data on "other" supply categories were cleaned for facility/data collector idiosyncrasies and sorted into existing or new supply categories as appropriate. Volume per unit was standardized to coincide with CMS units. For example, some facilities stated small disposable gloves came in a box of 50 pairs, while others stated they came in a box of 100 pairs. To coincide with the CMS standard of a box of 100 pairs, we divided the number of 50 pair-boxes a facility reportedly received by 2, effectively converting them to 100 pair-boxes.

Supply prices: Since facilities usually did not have price data available, we used secondary price data from the CMS, along with UNICEF Supply Catalogue prices (UNICEF 2016) when needed.

Supply Cost Formula: HIV Clinic Supplies Cost = per patient-year HIV clinic supply cost * # adult ART patients at clinic

ANNEX B: DATA ENVELOPMENT ANALYSIS METHODOLOGY

DEA is a non-parametric approach that uses linear programming techniques to estimate the relative efficiency in a group of DMUs in which all members are fairly homogenous and use an identical set of inputs to produce a variety of identical outputs. It allows multiple inputs and outputs and does not need a prior specification of functional form of the production function to be able to construct the efficiency frontier.

DEA can be estimated assuming VRS or constant returns to scale (CRS). The CRS assumption focuses on productivity regardless of the scale of operations while the VRS assumption takes into account the extent to which the scale of operation can affect productivity. Typically, the VRS assumption is preferred in the cases where the DMUs under analysis are not considered to be operating at their optimum scale (Jat and San Sebastian 2013). We use the VRS specification in this analysis.

The VRS assumption will give us information on scale efficiency for each DMU and indicate the type of returns to scale for scale inefficient DMUs: decreasing returns to scale (DRS) and increasing returns to scale (IRS). The DRS denotes that the size of the DMU is very large for the volume of its operations (output increases by a smaller proportion than each of the inputs) and the IRS means that the DMU is very small for its volume of activities (output may increase by a larger proportion than each of the inputs).

DEA also necessitates specification of an orientation: input-oriented or output-oriented. The input-oriented model assumes that the DMUs have an influence on the level of its inputs and will try to achieve efficiency by minimizing inputs for the same level of outputs. The output-oriented model uses output maximization to achieve efficiency. For the same level of inputs (assuming that DMU have limited influence on them), the goal is to produce a maximum level of output.

Recognizing that as public providers, the health facilities we are studying won't have much control on the level of inputs they can get (e.g., personnel, government subsidies), we chose to use the output-oriented model where, with their current level of inputs, the ART facilities are expected to maximize the number of patients they are treating.

ANNEX C: UNIT COSTS BY DISTRICT

Table C1: Mean (SD) Unit Costs (BWP) by District

District		ARVs		Labs		HumanResources		Supplies		Total	
Bobirwa (n=5)	Unit Cost	1,194	(131)	800	(213)	703	(305)	19	(0)	2,715	(261)
	% Total Unit Cost	44%		29%		26%		1%		100%	
Boteti (n=7)	Unit Cost	1,135	(138)	750	(132)	1,000	(372)	19	(0)	2,904	(487)
	% Total Unit Cost	39%		26%		34%		1%		100%	
Chobe (n=4)	Unit Cost	1,163	(93)	587	(200)	1,218	(1186)	19	(0)	2,987	(1,354)
	% Total Unit Cost	39%		20%		41%		1%		100%	
Francistown (n=9)	Unit Cost	1,088	(155)	749	(129)	427	(215)	19	(0)	2,283	(372)
	% Total Unit Cost	48%		33%		19%		1%		100%	
Gaborone (n=6)	Unit Cost	1,054	(183)	601	(185)	278	(83)	19	(0)	1,952	(284)
	% Total Unit Cost	54%		31%		14%		1%		100%	
Gantsi (n=4)	Unit Cost	1,267	(72)	701	(152)	1,459	(438)	19	(0)	3,447	(338)
	% Total Unit Cost	37%		20%		42%		1%		100%	
Goodhope (n=2)	Unit Cost	1,174	(155)	741	(200)	491	(23)	19	(0)	2,424	(332)
	% Total Unit Cost	48%		31%		20%		1%		100%	
Jwaneng (n=1)	Unit Cost	1,237	(0)	709	(0)	368	(0)	19	(0)	2,333	(.00)
	% Total Unit Cost	53%		30%		16%		1%		100%	
Kgalagadi (n=5)	Unit Cost	1,179	(111)	715	(105)	774	(400)	19	(0)	2,687	(501)
	% Total Unit Cost	44%		27%		29%		1%		100%	
Kgatleng (n=3)	Unit Cost	1,208	(211)	797	(231)	987	(589)	19	(0)	3,011	(575)
	% Total Unit Cost	40%		26%		33%		1%		100%	
Kweneng East (n=10)	Unit Cost	1,105	(191)	747	(233)	742	(1089)	19	(0)	2,613	(1,012)
	% Total Unit Cost	42%		29%		28%		1%		100%	

District		ARVs		Labs		HumanResources		Supplies		Total	
Kweneng West (n=7)	Unit Cost	1,134	(65)	843	(240)	988	(509)	19	(0)	2,985	(537)
	% Total Unit Cost	38%		28%		33%		1%		100%	
Lobatse (n=3)	Unit Cost	991	(124)	837	(87)	679	(302)	19	(0)	2,526	(451)
	% Total Unit Cost	39%		33%		27%		1%		100%	
Mabutsane (n=1)	Unit Cost	1,042	(0)	788	(0)	136	(0)	19	(0)	1,985	(0)
	% Total Unit Cost	52%		40%		7%		1%		100%	
Mahalapye (n=7)	Unit Cost	984	(159)	800	(148)	1,035	(1,242)	19	(0)	2,838	(1,261)
	% Total Unit Cost	35%		28%		36%		1%		100%	
Ngami (n=5)	Unit Cost	1,200	(98)	424	(170)	273	(84)	19	(0)	1,916	(232)
	% Total Unit Cost	63%		22%		14%		1%		100%	
North East (n=4)	Unit Cost	1,357	(147)	726	(69)	340	(106)	19	(0)	2,442	(180)
	% Total Unit Cost	56%		30%		14%		1%		100%	
Okavango (n=4)	Unit Cost	1,131	(110)	488	(172)	536	(199)	19	(0)	2,174	(239)
	% Total Unit Cost	52%		22%		25%		1%		100%	
Selebi-Phikwe (n=4)	Unit Cost	1,285	(160)	780	(155)	1,577	(2079)	19	(0)	3,660	(2,191)
	% Total Unit Cost	35%		21%		43%		1%		100%	
Serowe/ Palapye (n=12)	Unit Cost	1,134	(202)	629	(273)	378	(236)	19	(0)	2,161	(534)
	% Total Unit Cost	52%		29%		18%		1%		100%	
South East (n=4)	Unit Cost	954	(89)	700	(149)	965	(251)	19	(0)	2,638	(188)
	% Total Unit Cost	36%		27%		37%		1%		100%	
Southern (n=5)	Unit Cost	996	(132)	848	(153)	939	(1,057)	19	(0)	2,802	(1,149)
	% Total Unit Cost	36%		30%		34%		1%		100%	
Tutume (n=8)	Unit Cost	1,297	(187)	497	(194)	1,238	(987)	19	(0)	3,051	(877)
	% Total Unit Cost	42%		16%		41%		1%		100%	

Table C2: Mean (SD) Costs (BWP) of First and Second Line Drug Regimens by District*

District	Estimated # First Line Patients	Estimated # Second Line Patients	Mean Unit Cost for First Line ARVs (BWP)	Mean Unit Cost for Second Line ARVs (BWP)
Bobirwa (n=5)	90	9	1,091 (66)	2,438 (802)
Boteti (n=7)	134	6	1,049 (110)	3,162 (821)
Chobe (n=4)	79	1	1,127 (87)	3,929 (n/a)
Francistown (n=9)	167	11	1,039 (131)	1,726 (967)
Gaborone (n=6)	114	6	1,009 (240)	1,608 (461)
Gantsi (n=4)	75	5	1,202 (66)	2,246 (110)
Goodhope (n=2)	41	0	1,174 (219)	n/a
Jwaneng (n=1)	19	1	1,115 (n/a)	3,553 (n/a)
Kgalagadi (n=5)	99	1	1,187 (130)	524 (n/a)
Kgatleng (n=3)	53	7	1,087 (205)	2,134 (687)
Kweneng East (n=10)	185	15	1,037 (161)	1,801 (736)
Kweneng West (n=7)	134	6	1,096 (53)	1,931 (290)
Lobatse (n=3)	56	4	974 (144)	1,014 (478)
Mabutsane (n=1)	20	0	1,042 (n/a)	(n/a)
Mahalapye (n=7)	134	6	968 (167)	1,533 (274)
Ngami (n=5)	95	5	1,143 (83)	2,422 (615)
North East (n=4)	71	9	1,213 (112)	2,1736 (1085)
Okavango (n=4)	78	2	1,112 (95)	1,965 (n/a)
Selebi-Phikwe (n=4)	64	16	1,044 (134)	2,336 (305)
Serowe/Palapye (n=12)	220	17	1,043 (133)	2,274 (1046)
South East (n=4)	71	8	905 (143)	1,258 (132)
Southern (n=5)	96	3	963 (97	1,669 (1405)
Tutume (n=8)	146	14	1,124 (110)	3,072 (415)

*Facilities that had no second line drugs were not included in the average unit cost calculation; no standard deviation is provided because there was only one facility with an estimate in this district.

Table C3: Mean (SD) Utilization and Costs (BWP) of ART Lab Tests by District

	CD4		Viral Load		Renal Function Test		Full Blood Count		Red Blood Cell Count		White Blood Cell Count		Liver Function Test		Platelets		Overall (all labs)	
District	Utilization	Cost	Utilization	Cost	Utilization	Cost	Utilization	Cost	Utilization	Cost	Utilization	Cost	Utilization	Cost	Utilization	Cost	Utilization	Cost
Bobirwa (n=5)	1.8	110	1.81	645	0.31	17	0.13	4	0.07	1	0.07	3	0.1	5	0.05	1	4.51	800
	(0.55)	(34)	(0.58)	(208)	(0.28)	(16)	(0.12)	(4)	(0.10)	(2)	(0.10)	(4)	(0.15)	(8)	(0.10)	(3)	(0.79)	(213)
Boteti (n=7)	1.7	104	1.67	596	0.49	27	0.32	10	0.05	1	0.04	1	0.09	4	0.04	1	4.45	750
	(0.27)	(17)	(0.28)	(100)	(0.36)	(20)	(0.23)	(7)	(0.07)	(1)	(0.07)	(3)	(0.10)	(5)	(0.07)	(2)	(1.01)	(132)
Chobe (n=4)	1.34	82	1.3	463	0.28	15	0.19	6	0.15	3	0.08	3	0.2	10	0.08	2	3.64	587
	(0.51)	(31)	(0.53)	(187)	(0.18)	(10)	(0.17)	(5)	(0.15)	(3)	(0.13)	(5)	(0.15)	(8)	(0.13)	(4)	(0.89)	(200)
Francistown (n=9)	1.63	100	1.66	590	0.62	34	0.24	7	0.15	3	0.17	7	0.03	2	0.15	4	4.67	749
	(0.34)	(21)	(0.29)	(102)	(0.34)	(19)	(0.20)	(6)	(0.21)	(4)	(0.23)	(9)	(0.07)	(3)	(0.22)	(6)	(1.10)	(129)
Gaborone (n=6)	1.58	96	1.28	454	0.56	31	0.12	4	0.08	1	0.03	1	0.13	7	0.03	1	3.87	601
	(0.35)	(21)	(0.42)	(151)	(0.25)	(14)	(0.08)	(2)	(0.06)	(1)	(0.04)	(2)	(0.12)	(6)	(0.07)	(2)	(1.08)	(185)
Gantsi (n=4)	1.48	90	1.5	534	0.5	28	0.1	3	0.3	6	0.26	11	0.36	18	0.28	8	4.83	701
	(0.18)	(11)	(0.20)	(72)	(0.42)	(23)	(0.09)	(3)	(0.27)	(5)	(0.31)	(13)	(0.35)	(18)	(0.31)	(9)	(2.11)	(152)
Goodhope (n=2)	1.59	97	1.59	568	0.67	37	0.25	8	0.05	1	0.05	2	0.1	5	0.05	1	4.63	741
	(0.31)	(19)	(0.36)	(127)	(0.33)	(19)	(0.25)	(8)	(0.05)	(1)	(0.05)	(2)	(0.05)	(3)	(0.05)	(1)	(1.72)	(200)
Jwaneng (n=1)	1.95	119	1.55	552	0.15	8	0	0	0	0	0.25	10	0.15	8	0.15	4	4.25	709
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Kgalagadi (n=5)	1.56	95	1.45	516	0.65	36	0.33	10	0.32	6	0.42	17	0.35	18	0.37	11	5.53	715
	(0.23)	(14)	(0.23)	(82)	(0.17)	(10)	(0.24)	(7)	(0.18)	(4)	(0.07)	(3)	(0.23)	(11)	(0.11)	(3)	(0.74)	(105)
Kgatleng (n=3)	1.84	112	1.85	660	0.15	8	0.15	4	0.08	2	0.05	2	0.02	1	0.03	1	4.22	797
	(0.53)	(32)	(0.53)	(190)	(0.15)	(8)	(0.10)	(3)	(0.06)	(1)	(0.04)	(2)	(0.02)	(1)	(0.04)	(1)	(1.37)	(231)
Kweneng East (n=10)	1.65	100	1.71	607	0.41	23	0.2	6	0.08	2	0.09	4	0.05	2	0.06	2	4.24	747
	(0.44)	(27)	(0.52)	(186)	(0.38)	(21)	(0.18)	(5)	(0.09)	(2)	(0.11)	(5)	(0.08)	(4)	(0.09)	(2)	(1.58)	(233)
Kweneng West (n=7)	1.78	109	1.76	626	0.89	50	0.47	14	0.35	7	0.35	15	0	0	0.35	10	6.14	843
	(0.55)	(34)	(0.59)	(209)	(0.37)	(21)	(0.15)	(5)	(0.23)	(4)	(0.23)	(10)	(0)	(0)	(0.23)	(7)	(1.58)	(240)
Lobatse (n=3)	1.85	113	1.83	653	0.4	22	0	0	0.32	6	0.3	12	0.3	15	0.17	5	5.3	837
	(0.18)	(11)	(0.17)	(61)	(0.11)	(6)	(0)	(0)	(0.34)	(7)	(0.32)	(13)	(0.08)	(4)	(0.17)	(5)	(1.13)	(87)
Mabutsane (n=1)	1.65	101	1.6	570	0.9	50	0.3	9	0.25	5	0.3	12	0.5	25	0.3	9	5.85	788
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Mahalapye (n=7)	1.84	112	1.81	646	0.23	13	0.45	14	0.06	1	0.04	2	0.01	1	0.07	2	4.62	800
	(0.32)	(20)	(0.31)	(112)	(0.20)	(11)	(0.23)	(7)	(0.10)	(2)	(0.07)	(3)	(0.02)	(1)	(0.12)	(3)	(1.11)	(148)
Ngami (n=5)	1.29	79	0.94	335	0.1	6	0.12	4	0	0	0	0	0	0	0.05	1	2.5	424
	(0.55)	(34)	(0.39)	(138)	(0.03)	(2)	(0.14)	(4)	(0)	(0)	(0)	(0)	(0)	(0)	(0.08)	(2)	(0.98)	(170)
North East (n=4)	1.66	102	1.59	565	0.46	26	0.36	11	0.3	6	0.08	3	0.04	2	0.04	1	4.63	726
	(0.24)	(15)	(0.16)	(55)	(0.31)	(17)	(0.22)	(7)	(0.41)	(8)	(0.06)	(2)	(0.02)	(1)	(0.04)	(1)	(0.66)	(69)
Okavango (n=4)	1.16	71	1.13	401	0.25	14	0.09	3	0	0	0	0	0	0	0	0	2.63	488
	(0.41)	(25)	(0.42)	(150)	(0.17)	(9)	(0.10)	(3)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0.83)	(172)

	CD4		Viral Load		Renal Function Test		Full Blood Count		Red Blood Cell Count		White Blood Cell Count		Liver Function Test		Platelets		Overall (all labs)	
Selebi-Phikwe (n=4)	1.8	110	1.8	641	0.3	17	0.2	6	0.01	0	0.01	1	0.03	1	0	0	4.2	780
	(0.38)	(23)	(0.38)	(137)	(0.18)	(10)	(0.16)	(5)	(0.02)	(0)	(0.02)	(1)	(0.03)	(1)	0.00	0	(0.71)	(155)
Serowe/Palapye (n=12)	1.39	85	1.31	466	0.45	25	0.28	9	0.3	6	0.23	10	0.29	15	0.21	6	4.58	629
	(0.38)	(23)	(0.54)	(193)	(0.40)	(22)	(0.39)	(12)	(0.34)	(7)	(0.32)	(13)	(0.34)	(18)	(0.31)	(9)	(2.70)	(273)
South East (n=4)	1.62	99	1.48	527	0.6	33	0.23	7	0.08	1	0.08	3	0.28	14	0.15	4	4.64	700
	(0.17)	(10)	(0.26)	(94)	(0.39)	(22)	(0.15)	(5)	(0.08)	(2)	(0.08)	(3)	(0.48)	(24)	(0.15)	(4)	(1.57)	(149)
Southern (n=5)	1.94	119	1.85	659	0.7	39	0.24	7	0.08	2	0.06	2	0.17	9	0.07	2	5.25	848
	(0.20)	(12)	(0.30)	(109)	(0.52)	(29)	(0.24)	(7)	(0.12)	(2)	(0.12)	(5)	(0.34)	(17)	(0.14)	(4)	(1.59)	(153)
Tutume (n=8)	1.28	78	1.14	407	0.14	8	0.02	1	0	0	0	0	0.06	3	0.01	0	2.65	497
	(0.35)	(21)	(0.46)	(165)	(0.22)	(12)	(0.03)	(1)	(0)	(0)	(0)	(0)	(0.13)	(7)	(0.02)	(0)	(0.99)	(194)

Table C4: Mean (SD) Human Resources Unit Costs (BWP) by District

District	Doctors (BWP)	Nurses and Midwives (BWP)	Pharmacy (BWP)	All Clinical Cadres (BWP)	All Non-Clinical Cadres (BWP)	Total Unit Cost (BWP)
Bobirwa (n=5)	50 (62)	249 (124)	30 (48)	339 (171)	364 (262)	703 (305)
Boteti (n=7)	130 (209)	411 (150)	84 (113)	686 (259)	314 (204)	1,000 (372)
Chobe (n=4)	35 (61)	479 (367)	539 (933)	1,142 (1,076)	165 (106)	1,218 (1,186)
Francistown (n=9)	76 (31)	147 (77)	71 (86)	334 (136)	93 (128)	427 (215)
Gaborone (n=6)	92 (29)	94 (28)	31 (33)	228 (78)	50 (33)	278 (83)
Gantsi (n=4)	0 (0)	940 (544)	58 (101)	999 (491)	461 (209)	1,459 (438)
Goodhope (n=2)	49 (49)	167 (5)	0 (0)	235 (47)	256 (24)	491 (23)
Jwaneng (n=1)	157 (0)	50 (0)	0 (0)	227 (0)	140 (0)	368 (0)
Kgalagadi (n=5)	68 (136)	394 (305)	29 (58)	545 (382)	229 (67)	774 (400)
Kgatleng (n=3)	320 (391)	252 (119)	29 (41)	707 (610)	280 (271)	987 (589)
Kweneng East (n=10)	47 (44)	475 (869)	0 (0)	552 (845)	190 (263)	742 (1,089)
Kweneng West (n=7)	128 (90)	399 (382)	0 (0)	709 (514)	279 (123)	988 (509)
Lobatse (n=3)	0 (0)	336 (131)	94 (19)	458 (136)	221 (170)	679 (302)
Mabutsane (n=1)	0 (0)	103 (0)	0 (0)	103 (0)	33 (0)	136 (0)
Mahalapye (n=7)	484 (902)	396 (338)	0 0	886 (1,208)	150 (187)	1,035 (1242)
Ngami (n=5)	44 (39)	75 (47)	44 (38)	163 (71)	110 (119)	273 (84)
North East (n=4)	51 (38)	111 (87)	29 (49)	298 (83)	42 (25)	340 (106)

District	Doctors (BWP)	Nurses and Midwives (BWP)	Pharmacy (BWP)	All Clinical Cadres (BWP)	All Non-Clinical Cadres (BWP)	Total Unit Cost (BWP)
Okavango (n=4)	133 (49)	172 (70)	44 (47)	378 (137)	158 (118)	536 (199)
Selebi-Phikwe (n=4)	121 (171)	517 (334)	20 (29)	665 (486)	1,309 (1,782)	1,974 (2,265)
Serowe/Palapye (n=12)	63 (54)	190 (141)	31 (53)	306 (171)	72 (90)	378 (236)
South East (n=4)	40 (41)	398 (230)	140 (165)	582 (253)	383 (285)	965 (251)
Southern (n=5)	668 (1,060)	158 (90)	16 (25)	865 (1,059)	74 (39)	939 (1,057)
Tutume (n=8)	141 (191)	653 (704)	99 (228)	986 (847)	252 (158)	1,238 (987)

ANNEX D: EFFICIENCY RESULTS

Six hospitals (21 percent) are technically efficient in terms of "weak efficiency" (efficiency scores of 1) and 14 (48 percent) display "strong technical efficiency" (efficiency score is 1 and there are no slacks). Hospital 6, Hospital 8, Hospital 9, Hospital 10, and Hospital 12 have input slacks, that if addressed can put them on a better point on the hospital efficiency frontier (Table D1). For example, most of them could decrease their total costs for ARVs and laboratory tests with the current level of output.

There are 20 clinics (27 percent) with "strong" technical efficiency and 26 (36 percent) with "weak" technical efficiency (Table D2). Three of the "weak" technically efficient clinics exhibit both input and output slacks, meaning they can decrease the level of some inputs and increase the level of some outputs to reach a better position on the efficiency frontier. For example, compared to its peers, Clinic 57 could decrease its ARV total costs by BWP 20,514, its lab test costs by BWP 113,341, its FTE clinical and non-clinical staff by 0.66 and 0.18, respectively, while still treating the same number of patients. Furthermore, even with the previous decrease, Clinic 57 will have a potential to treat 4.14 more second line patients and remain technically efficient.

Thirteen health posts (72 percent) are technically efficient in terms of "strong efficiency," whereas five (28 percent) are technically efficient in terms of "weak efficiency" (Table D3).

Scale efficiency refers to the optimum size of a health facility's operations and the ability of hospital management to choose the optimum size of resources.

In terms of scale efficiency, 17 hospitals (59 percent) are operating at optimal scale (all of them are also technically efficient) and 13 hospitals (49 percent) display returns to scale. Seven hospitals have increasing returns to scale (they are too small for the volume of outputs they produce) and six have decreasing returns to scale (they are too large for the volume of output they produce).

In terms of scale efficiency, 20 clinics (27 percent) can be identified as efficient, 23 (32 percent) have increasing returns to scale, and 30 (41 percent) have decreasing returns to scale.

The scale efficiency column (Table D.3) shows zero for all health post facilities meaning all of them are scale efficient (not too large, not too small in terms of scale of production compared to their actual output).

Table D1: Efficiency Scores and Input/Output Slacks for Hospitals

Hospital	Technica Efficiency Score	Input Slacks					Output Slacks		Scale Efficiency: Returns to Scale
		ARV total costs (BWP)	Lab tests total costs (BWP)	Clinical supplies total costs (BWP)	FTE clinical staff	FTE Non-clinical staff	Number first line patients	Number second line patients	
Hospital 7	1	.	0	.	.	0	.	0	0
Hospital 11	1	.	0	0	0	.	.	0	0
Hospital 13	1	0	0	0	0	.	.	0	0
Hospital 14	1	0	0	0	.	.	.	.	0
Hospital 16	1	0	0	0	.	.	.	.	0
Hospital 19	1	.	0	0	0	.	.	0	0

Hospital	Technica Efficiency Score	Input Slacks					Output Slacks		Scale Efficiency: Returns to Scale
		ARV total costs (BWP)	Lab tests total costs (BWP)	Clinical supplies total costs (BWP)	FTE clinical staff	FTE Non-clinical staff	Number first line patients	Number second line patients	
Hospital 21	1	0	0	0	.	0	0	.	0
Hospital 22	1	0	0	.	0	0	.	.	0
Hospital 23	1	.	0	.	.	0	.	0	0
Hospital 24	1	0	0	0	0	.	.	0	0
Hospital 26	1	0	0	.	0	0	.	.	0
Hospital 18	1	0	.	.	.	0	.	0	DRS
Hospital 29	1	0	.	.	0	.	.	.	0
Hospital 2	1	.	0	.	.	0	.	0	0
Hospital 27	1	0	.	.	.	.	.	.	0
Hospital 12	1	119,487	81,296	.	.	2.87	.	0	IRS
Hospital 8	1	229,827	141,288	.	2.45	6.77	.	.	IRS
Hospital 10	1	87,544	352,926	0	4.71	.	.	.	IRS
Hospital 9	1	174,137	482,121	.	0.07	1.67	.	0	0
Hospital 6	1	288,696	1,021, 467	.	.	1.01	.	0	0
Hospital 15	0.995	686,952	822,694	.	2.1	.	.	.	DRS
Hospital 1	0.995	.	543,467	0	6.76	.	.	.	IRS
Hospital 3	0.993	402,002	716,421	.	0	.	.	.	IRS
Hospital 25	0.992	0	57,550	.	4.14	0.43	.	.	DRS
Hospital 4	0.99	516,454	791,568	.	0.58	8.77	.	.	DRS
Hospital 17	0.984	483,173	312,042	.	3.24	.	.	.	DRS
Hospital 5	0.974	407,117	56,279	.	.	5.27	.	.	IRS
Hospital 28	0.973	207,207	2,453	.	.	.	.	.	IRS
Hospital 20	0.944	398,703	.	.	.	.	.	.	DRS

Note: "." in the results table represents values so small (less than 10 to the minus 9 power) that they can be ignored.

Table D2: Efficiency Scores and Input/Output Slacks for Clinics

Clinic	Technical Efficiency Score	Input Slacks					Output Slacks		Scale Efficiency: Returns to Scale
		ARV total costs (BWP)	Lab tests total costs (BWP)	Clinical supplies total costs (BWP)	FTE clinical staff	FTE non-clinical staff	Number first line patients	Number second line patients	
Clinic 5	1	.	0	.	0	.	.	0	0
Clinic 6	1	0	.	.	0	.	.	0	0
Clinic 13	1	0	0	0	0	.	.	.	0
Clinic 40	1	.	0	.	0	0	.	.	0
Clinic 41	1	0	0	.	.	0	.	.	0
Clinic 42	1	0	0	.	0	.	.	0	0
Clinic 52	1	0	0	0	0	.	.	0	0
Clinic 53	1	0	0	.	0	.	.	0	0
Clinic 56	1	.	0	0	0	0	.	0	0
Clinic 62	1	.	0	0	0	0	.	.	0
Clinic 68	1	0	.	0	.	.	.	0	0
Clinic 69	1	0	0	.	0	0	0	.	0
Clinic 70	1	0	0	0	.	.	.	0	0

Clinic	Technical Efficiency Score	Input Slacks					Output Slacks		Scale Efficiency: Returns to Scale
		ARV total costs (BWP)	Lab tests total costs (BWP)	Clinical supplies total costs (BWP)	FTE clinical staff	FTE non-clinical staff	Number first line patients	Number second line patients	
Clinic 72	1	.	0	.	.	0	.	.	0
Clinic 13	1	.	0	.	0	.	.	0	DRS
Clinic 4	1	0	.	.	.	0	.	0	DRS
Clinic 18	1	.	0	.	0	0	.	0	DRS
Clinic 38	1	0	.	.	.	0	.	0	DRS
Clinic 59	1	.	0	.	.	0	.	0	DRS
Clinic 60	1	.	0	.	0	0	.	.	DRS
Clinic 24	1	0	.	.	.	.	.	0	0
Clinic 66	1	0	0	.	0	0	.	0	DRS
Clinic 20	1	.	.	.	0	.	.	.	0
Clinic 2	1	0	.	.	0	.	.	.	DRS
Clinic 50	1	81,973	28,598	0	0.8	1.86	.	.	IRS
Clinic 73	1	58,807	299,746	.	3.11	0.12	.	0	IRS
Clinic 36	1	228,271	149,770	.	0.6	1.66	.	.	0
Clinic 32	1	227,332	263,678	.	1.3	0.48	.	.	IRS
Clinic 43	1	254,910	238,276	376	3.48	0.27	.	.	IRS
Clinic 3	1	160,001	372,998	.	0.17	.	.	.	0
Clinic 39	1	152,192	447,823	.	0.35	.	.	.	IRS
Clinic 35	1	450,569	241,983	.	3.93	0.93	.	.	0
Clinic 64	1	161,922	721,329	.	3.8	0.11	.	.	0
Clinic 7	1	378,263	1,037,088	.	0.64	.	0	.	0
Clinic 58	1	1,052,827	767,850	.	3.9	0	.	.	0
Clinic 49	1	587,658	0	.	1.92	1.84	.	.	DRS
Clinic 37	1	.	233,045	.	0.68	.	.	.	DRS
Clinic 30	1	74,456	112,726	.	0.39	.	.	.	IRS
Clinic 12	1	106,608	.	.	1.81	.	.	0	IRS
Clinic 26	1	648,791	12	.	2.45	0.47	.	.	DRS
Clinic 47	1	3,771,226	.	.	3.24	0.11	.	.	DRS
Clinic 34	1	80,824	162,730	.	.	0.06	.	.	IRS
Clinic 25	1	.	270,430	.	9.17	.	.	0.7	IRS
Clinic 27	1	0	.	.	2.18	.	.	1.2	DRS
Clinic 57	1	20,514	113,341	.	0.66	0.18	.	4.14	IRS
Clinic 45	1	865,206	0	.	0.68	0.13	.	.	DRS
Clinic 54	0.999	.	1,086,733	.	.	2.11	.	.	DRS
Clinic 46	0.999	0	1,042,666	.	6.2	1.58	.	.	DRS
Clinic 55	0.999	578,292		.	0.25	1.45E-05	.	.	DRS
Clinic 9	0.998	521,158	995,668	0	1.63	.	.	.	IRS
Clinic 28	0.998	60,027	313,145	.	4.04	.	.	.	IRS
Clinic 33	0.997	56,252	72,460	.	1.88	0.86	.	4.09	IRS
Clinic 11	0.997	.	5	.	0.68	1.87	.	.	DRS
Clinic 31	0.997	103,080	259,478	.	0.3	.	.	0.004	IRS
Clinic 71	0.996	1	594,477	.	1.67	2.35	.	.	DRS
Clinic 44	0.996	31,531	473,472	.	2.25	0.36	.	.	IRS
Clinic 10	0.995	42,133	156,117	.	2.42	.	.	.	IRS
Clinic 17	0.995	129,409	307,159	.	2.88	.	.	.	IRS
Clinic 14	0.995	.	225,841	.	1.77	.	.	.	IRS
Clinic 51	0.994	.	65,741	.	2.49	2.56	.	.	DRS
Clinic 29	0.993	0	1,121,909	.	4.21	0.52	.	.	DRS

Clinic	Technical Efficiency Score	Input Slacks					Output Slacks		Scale Efficiency: Returns to Scale
		ARV total costs (BWP)	Lab tests total costs (BWP)	Clinical supplies total costs (BWP)	FTE clinical staff	FTE non-clinical staff	Number first line patients	Number second line patients	
Clinic 21	0.993	13,367	101,303	.	0.27	.	.	.	DRS
Clinic 67	0.993	0	228,958	.	3.04	4.3	.	.	DRS
Clinic 61	0.991	0	329,323	.	2.47	3.45	.	.	IRS
Clinic 48	0.991	355,687	221,241	.	3.69	0	.	.	IRS
Clinic 19	0.989	.	615,520	.	0.75	1.25	.	.	DRS
Clinic 63	0.983	1,691	0	.	3.03	0.08	.	.	DRS
Clinic 15	0.98	.	151,847	.	3.63	0.95	.	.	DRS
Clinic 23	0.979	103,857	0	.	3.22	.	.	0.92	DRS
Clinic 16	0.96	35,350	170,865	.	2.04	0.07	.	.	DRS
Clinic 8	0.949	51,930	390,239	.	3.99	.	.	.	IRS
Clinic 22	0.943	117,052	326,637	.	0.84	.	.	.	IRS
Clinic 65	0.871	20,502	31,913	.	0.13	1.57	.	2.46	IRS

Note: "." in the results table represents values so small (less than 10 to the minus 10 power) that they can be ignored.

Table D3: Efficiency Scores and Input/Output Slacks for Health Posts

Health Post	Technical Efficiency Score	Input Slacks					Output Slacks		Scale Efficiency: Returns to Scale
		ARV total costs (BWP)	Lab tests total costs (BWP)	Clinical supplies total costs (BWP)	FTE clinical staff	FTE Non-clinical staff	Number first line patients	Number second line patients	
Health Post 1	1	0	0	0	0	.	.	.	0
Health Post 2	1	0	0	0	0	.	.	0	0
Health Post 6	1	.	0	0	.	.	0	.	0
Health Post 8	1	0	.	0	.	.	.	0	0
Health Post 9	1	.	0	0	.	.	.	0	0
Health Post 10	1	0	.	0	.	.	.	.	0
Health Post 11	1	.	0	0	.	.	.	0	0
Health Post 13	1	0	.	0	.	.	.	.	0
Health Post 14	1	0	0	0	.	0	.	0	0
Health Post 15	1	0	0	0	0	.	.	0	0
Health Post 16	1	.	0	0	.	.	.	0	0
Health Post 17	1	.	0	0	.	.	.	.	0
Health Post 18	1	0	.	0	0	.	0	.	0
Health Post 4	1	0	.	.	0	.	.	0	0
Health Post 7	1	.	.	.	.	.	.	.	0
Health Post 12	1	7,130	3,535	.	0.33	0.77	0	.	0
Health Post 5	1	2,987	20,357	0	.	0.12	.	.	0
Health Post 3	1	24,439	24,115	.	0.2	0.2	.	0	0

Note: "." in the results table represents values so small (less than 10 to the minus 11 power) that they can be ignored.

ANNEX E: REFERENCES

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