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Orvalho Augusto

Shedding light on the “black box” of delivery: Evaluating the impact of a health
system strengthening intervention in Sofala province, Mozambique

Orvalho Augusto

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Reading Committee:

Kenneth Gimbel-Sherr, Chair

Bradley Wagenaar

Jonathan Wakefield

Program Authorized to Offer Degree:

Global Health

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Abstract

Shedding light on the “black box” of delivery: Evaluating the impact of a health systems strengthening intervention in Sofala province, Mozambique

Orvalho Augusto

Chair of the Supervisory Committee:
Kenneth Gimbel-Sherr
Department of Global Health

Limited high-quality information exists on optimal approaches to improve health system performance in low-and middle-income countries (LMICs). In the present study, we evaluate the effects of a 5-year health system strengthening program focused in improving the routine data quality and its use; enhancing management and planning capacity and funding district plans; and building capacity for operations research to guide system-strengthening efforts, to ultimately reduce under-5 mortality in Sofala province, Mozambique. Also, we document resilience of the Mozambique health system to the COVID-19 crisis.

TABLE OF CONTENTS

List of Figures	v
List of Tables	vi
CHAPTER 1: INTRODUCTION	1
CHAPTER 2: EVALUATING THE MOZAMBIQUE AFRICAN HEALTH INITIATIVE ON MATERNAL AND CHILD HEALTH COVERAGE AT THE COMMUNITY LEVEL.....	6
Abstract.....	6
Background.....	7
African Health Initiative and Mozambique System Intervention	9
Methods	11
Study Design and Study Settings	11
Mozambique PHIT Project Implementation.....	11
Conceptual Framework	14
Data Sources and Variables	14
Outcomes	15
Statistical Analysis	17
Ethical Considerations.....	19
Results	19
General and Demographic Characteristics	19
Health System Outputs	22

Mother Care Services	22
Childcare Services—Immunization and Treatment Care Seeking	23
Health System Outcomes	24
Child Mortality.....	24
Discussion.....	31
Strengths and Limitations.....	32
Conclusion	34
Abbreviations.....	34
References	36
CHAPTER 3: HEALTH SERVICES PROVISION EFFECT OF THE MOZAMBIQUE AFRICAN	
HEALTH INITIATIVE	44
Abstract.....	44
Background.....	45
Methods	47
Study Design and Study Settings	47
Data Sources.....	48
Data Processing	49
Variables	51
Statistical Analysis	52
Ethical Considerations.....	55
Results	55

General and Pre-Intervention Characteristics	55
Maternal Health Service Delivery Outcomes	57
Child Health Service Delivery Outcomes	58
Discussion.....	63
Limitations	65
Conclusions	65
Acknowledgments	66
References	67
CHAPTER 4: EARLY EFFECTS OF COVID-19 ON MATERNAL AND CHILD HEALTH SERVICE DISRUPTION IN MOZAMBIQUE	89
1. Abstract.....	90
2. Introduction.....	92
3. Materials and Methods	93
3.1. Study design	93
3.2 Study setting and overview of Mozambique and its health system	94
3.3 Data sources and processing.....	98
3.4 Statistical analysis	99
3.5 Ethical considerations.....	101
4 Results.....	101
4.2 Trends before 2020.....	101
4.3 Service disruptions	104

4.4	Mortality impact	107
5	Discussion	107
5.2	Strengths and limitations	111
6	Conclusions	112
6.2	Abbreviations	114
6.3	References	115
Chapter 5: Overall Conclusions		120

LIST OF FIGURES

Figure 2.1 - PHIT Mozambique strategies and their anticipated effects on WHO health system building blocks.	13
Figure 2.2 - African Health Initiative common conceptual model.	14
Figure 2.3 - Absolute differences of the output and outcome indicators from 2010 to 2015.....	39
Figure 2.4 - Difference in proportion differences between 2010 to 2015 of the output and outcome indicators.....	40
Figure 2.5 - Proportion ratios of the output and outcome indicators from 2010 to 2015	41
Figure 2.6 - Ratio of proportion ratios between 2010 to 2015 of the output and outcome indicators	42
Figure 3.1. Yearly relative level changes of the outcomes in each segment of time for Manica and Sofala provinces	60
Figure 3.2. Sofala additional multiplicative change (RRR – ratio of relative ratios) relative to Manica	61
Figure 3.3 – Estimated model predictions overlapped to observed data.....	62
Figure 4.1 – Map of Mozambique with administrative divisions (provinces). Maputo City (not in the illustration) is contained within Maputo Province. Source: Darbyshire et al 2019.....	96

LIST OF TABLES

Table 2.1. Outcome indicators assessed to determine impact of PHIT Partnership project.....	16
Table 2.2. Covariates (explanatory factors) included in the adjusted analysis.....	17
Table 2.3. Number of children and their mothers, and number of observations by indicator and survey	20
Table 2.4. Province characteristics in 2010.....	21
Table 2.5. Direct survey estimates of health service coverage (in percentage) and mortality (per 1000 live births) – point estimates and 95% confidence interval in brackets	25
Table 2.6. Unadjusted model-based estimates of health service coverage (in percentage) and mortality (per 1000 live births) – point estimates and 95% credible interval in brackets	27
Table 2.7. Adjusted model-based estimates of health service coverage (in percentage) and mortality (per 1000 live births) – point estimates and 95% credible interval in brackets.....	29
Table 3.1. Number of health facilities processed.	50
Table 3.2. Demographic characteristics of Sofala and Manica provinces and health facilities included in the analysis.....	55
Table 3.3. Annual relative changes in outcomes by time segment in Manica and Sofala provinces and multiplicative changes (RRR, ratio of relative ratios) in Sofala relative to Manica	59
Table 3.4 - Random-effects summary.....	61
Table 4.1. Mozambique demographic characteristics by province	97
Table 4.2. Selected maternal and child health indicators for analysis between January 2017 and December 2019 (district-month counts).....	102
Table 4.3. Mixed-effect negative binomial regression coefficients for selected indicators, January 2017 to December 2019	103
Table 4.4. Mozambique observed and expected service losses by indicator, 2020 and first quarter of 2021	105
Table 4.5. National-level relative reduction in service counts by indicator and month, 2020 and first quarter of 2021.....	106

Table 4.6. Mozambique's relative reduction in service counts, by indicator and month for 2020 and first quarter of 2021.....	105
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DEDICATION

To my mother Isabel for her ongoing love, support, and all sacrifices

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Chapter 1: Introduction

CHAPTER 1: INTRODUCTION

Overall, between 1990 and 2015, Mozambique reduced the under-5 mortality rate (U5MR) from 240 to 79 deaths per 1000 live births, an average annual rate of reduction of 4.5%¹. Although reaching the Millennium Development Goal 4 (MDG 4; to reduce the under-5 mortality rate by two-thirds between 1990 and 2015) target, the U5MR is still high, and the levels and reduction trends were not similar across country with large parts of the country still experiencing high U5MR².

The main causes of death before the age of 5 years are preventable, with at least two-thirds attributable to infections (including neonatal sepsis, pneumonia and diarrhea) and malaria³. According to the post-2007 census survey alone, malaria, HIV, and pneumonia represented, respectively, 42.3%, 13.4%, and 6.4% of all causes of death^{2,4}. Ten years after, a newly established countrywide community mortality surveillance shows that although the importance of HIV among children under 5 deaths reduced, the overall composition of infection, malaria, and HIV represented 81.2% among the deaths³.

Globally, there has been an increasing understanding of the role of national health systems in delivering proven, efficacious interventions. Health systems are viewed as the main instrument for closing the knowledge-action gap for health interventions⁵⁻⁷. However, myriad questions on which models are most effective at strengthening health systems remain unanswered. For example, should the traditional model of focusing on specific diseases prevail (the vertical approach) or a relatively new approach to delivering services through publicly financed health systems be spread (the horizontal)? Or is it possible to combine both approaches (diagonalization)? And how to best use limited resources to strengthen health systems while maximizing the beneficial effects on

populations they serve, given the complexity of health systems (the ‘black box’) and the potential for investing (the resource ‘black hole’)?⁵

In this context, in 2009 the Doris Duke Charitable Foundation (DDCF) launched the African Health Initiative (AHI) “...to help catalyze a shift from current public health focus on single-disease programs to an emphasis on strengthening health systems to effectively deliver integrated primary care to underserved populations”. AHI was created as a research program to help understand how HSS can improve population health, shedding light on how to make interventions with solid evidence base available, accessed, and used by served populations. Following a competitive application process, five countries were chosen (Ghana, Mozambique, Rwanda, Tanzania, and Zambia) to implement distinct, large HSS interventions. All countries agreed to a common evaluation framework comprising core indicators, though each program was distinct in intervention and evaluation designs^{8,9}.

The Mozambique Partnership was a seven-year grant with an overall goal to improve the health outcomes in all 13 districts in Sofala Province by strengthening health systems and improving the delivery of integrated PHC. The three major aims included: 1) to strengthen integrated health systems management in Sofala at district and provincial levels; 2) to improve quality of routine data and develop appropriate tools to facilitate decision-making for provincial and district managers; and 3) to build capacity for and conduct innovative operations research (OR), including program evaluation, in order to guide integration and system-strengthening efforts. This dissertation work reports on the efforts to evaluate the impact of the Mozambique HSS project on population-level health and health system outputs.

Sofala Province was chosen based on a long history of supportive and successful collaboration between the Ministry of Health and its Sofala Provincial Health Directorate (Direcção Provincial

de Saúde (DPS) de Sofala), the Universidade Edudardo Mondlane (UEM) Medical School, Health Alliance International (HAI), the University of Washington (UW) Department of Global Health¹⁰. These institutions have over 25 years of collaborative experience in central Mozambique. With technical support from HAI advisors, Provincial health authorities were responsible for designing and implementing the PHIT model. The CIOB, an applied research arm of the Mozambique Ministry of Health's National Health Institute developed in 2007 with financial and technical support from HAI and UW, supports the development of operations research in the province and for the PHIT project. UEM faculty co-lead the Mozambique PHIT partnership, train and mentor master's level students from Sofala province, and provide technical support for associated applied research in Sofala. UW faculty supported the implementation research and led evaluation efforts¹⁰. This dissertation work focuses on reporting the results of the PHIT Mozambique. First, the intervention impact on maternal and child health service access and utilization and mortality rates is assessed using representative community surveys carried out in Mozambique between 2003 and 2015 through interrupted time series analysis. Second, impact on service delivery using data from the Ministry of Health routine health information system (MB; módulo básico). Third, to document Mozambique's health system under COVID and how it responded.

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Chapter 2: Evaluating the Mozambique African Health Initiative on Maternal and Child Health Coverage at the Community Level

CHAPTER 2: EVALUATING THE MOZAMBIQUE AFRICAN HEALTH INITIATIVE ON MATERNAL AND CHILD HEALTH COVERAGE AT THE COMMUNITY LEVEL

Abstract

Background: Limited high-quality information exists on optimal approaches to improve health system performance in low-and middle-income countries (LMICs). In the present study, we evaluate the effects of a 5-year health system strengthening program focused in improving the routine data quality and its use; enhancing management and planning capacity and funding district plans; and building capacity for operations research to guide system-strengthening efforts, to ultimately reduce under-5 mortality in Sofala province, Mozambique.

Methods: We used multiple community surveys (DHS 1997, DHS 2011, IMASIDA 2015, and INCOMAS 2016) to conduct a time-series analysis at the provincial level comparing Sofala Province (the PHIT Partnership intervention) with Manica Province (the control). The outcomes of our analyses included: community level maternal child health services utilization (coverage of at least 4 antenatal care visits (ANC4+), institutional deliveries (ID), proportion of women receiving 2 or more doses of intermittent preventive treatment for malaria (IPTp2+), skilled birth attendance (SBA), cesarean section rate (Cesar), diphtheria, tetanus, and pertussis vaccine coverage (DTP3), full immunization coverage (Fullimune), fever treatment (TxFever), acute respiratory infection treatment (TxARI), oral rehydration (TxDiar) for children with diarrhea) and infant and child mortality rates. We used both uncontrolled (to estimate gains within the province) and controlled analyses (to estimate additional gains Sofala had relative to Manica).

Results: Sofala province observed an increase in coverage of the ANC4+ of 11.9% (95%CrI: 5.4 to 18.4%) and IPTp2+ of 11.3% (95%CrI: 1.2 to 24.1), whereas Manica observed a

6.8% (-6.8, 95%CrI: -12.3 to -1.3) in ANC4+ and 8.9% (-8.9, 95%CrI: -20.8 to 3.3) in IPTp2+ reductions. Therefore, Sofala province observed additional gains beyond Manica province in ANC4+ of 18.7% (95%CrI: 11.5 to 26.0) and in IPTp2+ of 20.2% (95%CrI: 4.7 to 36.7). Regarding the uncontrolled ITS, both Manica and Sofala experienced significant reductions in mortality. However, the PHIT-Mozambique intervention province did not observe gains beyond the control.

Conclusions: PHIT Partnership was not associated with mortality reduction beyond observed in control provinces. However, it improved some health system service coverage.

Background

The World Health Organization (WHO) proposed the following working definition for health system: “all activities whose purpose is to promote, restore, or maintain health” as expressed in the report, *The World Health Report 2000: Health Systems Improving Performance*¹. Since then, the concept of “health outcome” was expanded from just goodness (i.e., responding well to what people expect) of health to include fairness (i.e., responding equally to everyone without discrimination). In addition, the report advances the health systems building block framework, which was updated in 2010 and is instrumental in helping understand how concrete actions (interventions) and their influences at the health system level are transformed into health outcomes².

The concept of a “health system” existed long before it was defined by WHO in 2000. However, the paradigm of preventing and controlling diseases was limited to focusing on conditions with the highest disease burden—an idea inspired by the success of global efforts to eliminate diseases such as smallpox. This led to vertical interventions and investment in priorities according to an agenda established by international organizations.

After colonial liberation across sub-Saharan Africa in the 1960s and 1970s, the Declaration of Alma-Ata³ was launched in 1978, which established the idea of primary health care. The primary health care movement specified a collection of health system service components. Eventually, the primary health care movement was neglected, and subsequently, resources were concentrated in a few interventions to improve child health—at the expense of support for broad health systems and programs that represented a more horizontal health systems approach^{4,5}. In the last few decades, we have witnessed increased investments in health systems development and a proliferation of scientific and policy literature supporting health systems development⁶. The concept of focusing on a specific disease while supporting the broad health system activities emerged—the diagonal approach—is a compromise between the vertical and horizontal approaches or health system strengthening (HSS) as commonly known. Nevertheless, there has been an increasing understanding of HSS as a means to universal health coverage to reach the sustainable development goals⁷, and increasing number of studies in HSS are conducted in low- and middle-income countries (LMICs) with many showing effective strategies HSS particularly in maternal, child and neonatal health field^{8,9}. However, many of these studies focuses on service delivery, or health workforce and health financing virtually disregarding the leadership and governance and the notion a health system is made of multiple components⁸. Furthermore, there is limited evidence on effective HSS due methodological issues such inappropriate evaluation design for impact attribution¹⁰, and as the health systems are complex adaptive systems and highly context sensitive¹¹ to provide generalizable guidance particularly for large-scale HSS work.

Under the call for African Health Initiative for large-scale interventions to reduce mortality, a HSS project was implemented in Sofala province in Mozambique. Pre-intervention work identified two key gaps as 1) need for management training and province and district levels and 2)

need for data quality improvement and utilization. The HSS intervention was designed to address these in a span of five years to reduce maternal and child mortality.

African Health Initiative and Mozambique System Intervention

In this context, the Doris Duke Charitable Foundation in 2007 launched the African Health Initiative “...to help catalyze a shift from current public health focus on single-disease programs to an emphasis on strengthening health systems to effectively deliver integrated primary care to underserved populations”¹². The African Health Initiative was created to help understand how HSS can improve population health, shedding light on how to make interventions with a solid evidence base available, accessed, and used by served populations. For the phase 1 of the project a competitive application was launched and five countries were chosen (Ghana, Mozambique, Rwanda, Tanzania, and Zambia) to implement distinct, large HSS interventions. Each country created its own Population Health Implementation and Training (PHIT) Partnership project. All countries agreed to a common evaluation framework that included core indicators, although each program was distinct in its intervention and evaluation designs ^{12,13}. The partnership projects in the five countries emphasize integrated interventions that encompass multiple components of the WHO health system building blocks, rather than historically targeted HSS interventions such as performance-based financing or community health worker programs ^{14–19}. Here we focus on reporting the results of the Mozambique PHIT Partnership.

The Mozambique PHIT Partnership was established through a seven-year grant, with the overall goal to improve health outcomes in all 13 districts of Sofala Province by strengthening health systems and improving the delivery of integrated primary health care services. The three major project aims were: (1) strengthen integrated health systems management in Sofala at the district and provincial levels; (2) improve the quality of routine data and develop appropriate tools

to facilitate decision making for provincial and district managers; and (3) strengthen capacity for and conduct innovative operations research, including program evaluation, in order to guide integration and system strengthening efforts.

Sofala Province was chosen based on a long history of supportive and successful collaboration between the Mozambique Ministry of Health and its Sofala Provincial Health Directorate (Direcção Provincial de Saúde de Sofala), the Eduardo Mondlane University School of Medicine, Health Alliance International, and the University of Washington Department of Global Health ¹⁵. Combined, these institutions have over 25 years of collaborative experience in central Mozambique. With technical support from Health Alliance International advisors, provincial health authorities were responsible for designing and implementing the PHIT Partnership model. The Beira Operations Research Center is an applied research arm of the Mozambique Ministry of Health's National Health Institute, developed in 2007 with financial and technical support from Health Alliance International and the University of Washington, supported the development of operations research in the province and for the PHIT Partnership project. Eduardo Mondlane University medical faculty co-led the Mozambique PHIT Partnership, trained and mentored master's level students from Sofala Province, and provided technical support for associated applied research in Sofala. University of Washington faculty supported implementation research and led evaluation efforts ¹⁵.

Here, we describe our findings from an impact evaluation conducted on the Mozambique PHIT Partnership project and its effects on community-level changes in key maternal and child health indicators using four community health surveys.

Methods

Study Design and Study Settings

The impact assessment of the PHIT Partnership project in Mozambique was designed to use interrupted time-series analysis (both uncontrolled and controlled) using data from routine health information systems and community surveys conducted across the country. PHIT was implemented in Sofala Province between 2009 and 2015 and aimed to cover all 13 districts and 146 health facilities. Sofala Province is located in the central region of Mozambique and is considered one of the poorest of the 11 provinces in the country. By 2009, the population of Sofala was 1.8 million, of which 63% were in rural areas, and 62% of the population lived on the Beira corridor (the transportation route that links the seaport of Beira to Zimbabwe). Sofala Province had higher rates of child mortality (infant mortality rate of 81 per 1,000 live births and under-five mortality rate of 134 per 1,000 live births), a higher burden of HIV (15.5% of adults ages 15-49, and about 60,000 needing antiretroviral treatment, of whom 40% were below the age of 15) and high levels of child malnutrition (prevalence of chronic malnutrition among children under five years of age is 35.7%) compared with other provinces in the country²⁰⁻²².

Mozambique PHIT Project Implementation

As described elsewhere¹⁵, the hallmark of the Mozambique PHIT Partnership is its integration into the Ministry of Health's management structure at the provincial level to facilitate sustainability and scalability of activities. Partnership technical personnel work within Ministry of Health offices to strengthen the capacity of staff from operational and program sectors to conduct routine management activities rather than developing parallel systems. This integrated approach was designed to enable uptake of new ideas and methodologies from the PHIT Partnership into the health system, leading to rapid, broad-scale, and sustainable implementation of activities across Sofala Province. Mozambique PHIT partners include the Sofala Provincial Health Directorate,

Health Alliance International, the Ministry of Health's Beira Operations Research Center, Eduardo Mondlane University School of Medicine, and the University of Washington Departments of Global Health and Industrial and Systems Engineering. Given the integrated nature of the partnership approach, the project aims were designed to lead to improvements across all six health system building blocks identified by WHO (Figure 2.1) ²³ through 3 activities:

- Activity 1: Improve the quality of routine data and develop appropriate tools to facilitate decision making for provincial and district managers - The effects of this activity were reported elsewhere ²⁴. It is a data quality assurance and audit and feedback action involving HIS personnel and managers at district and provincial levels and ministry of health and elements of the academic institutions involved in PHIT-Mozambique.

- Activity 2: Strengthen integrated health systems management and planning capacity at district and provincial levels - Mozambique PHIT Partnership activities were designed to promote data-driven decision making by strengthening capacity in management and leadership through a mix of in-service trainings using ministry of health training curriculum²⁵ and post-training coaching of health managers.
- Activity 3: Strengthen capacity and conduct innovative operations research to guide integration and system strengthening efforts through applied systems analysis and other operations research to guide service integration efforts, increase identification of modifiable service delivery barriers, and evaluate the effectiveness of potential innovations before scaling up throughout the province. Also, by providing technical and financial support for the

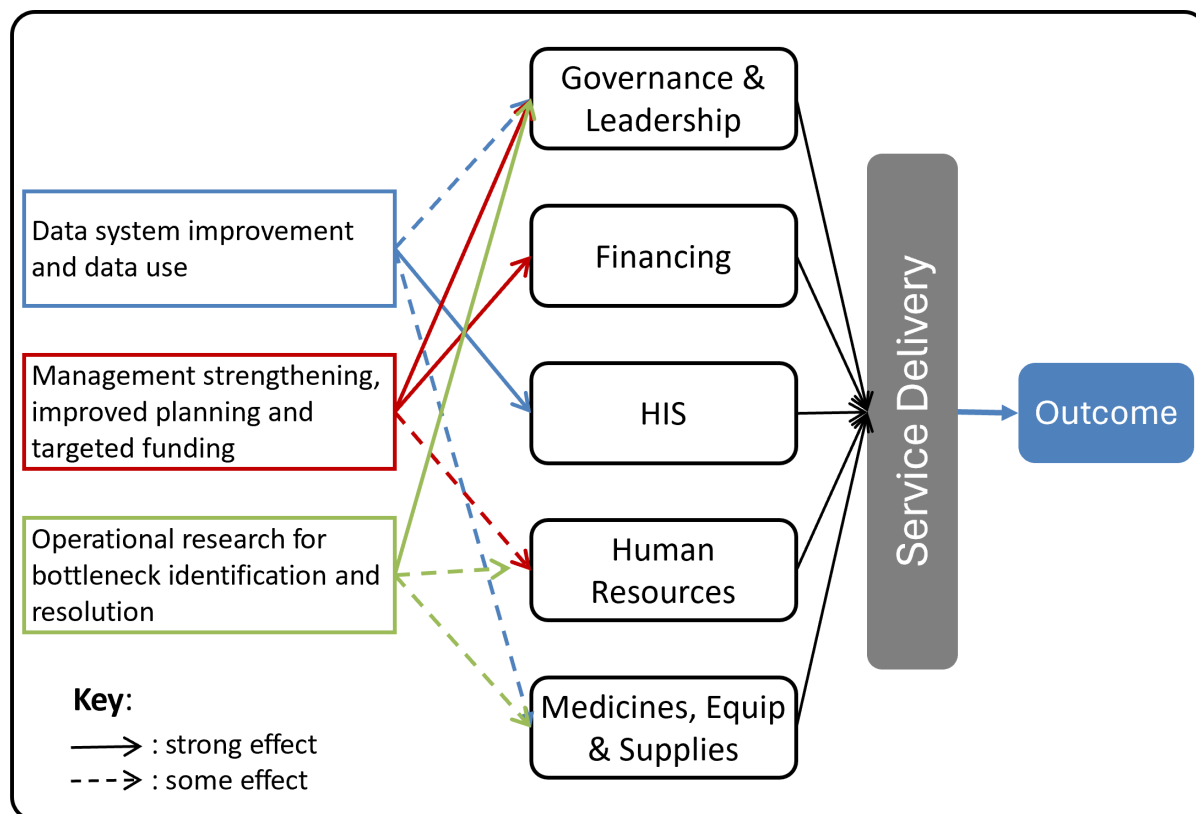


Figure 2.1 - PHIT Mozambique strategies and their anticipated effects on WHO health system building blocks. Adapted from Sherr et al¹⁵

Ministry of Health's Beira Operations Research Center based in Sofala, master's level public

health training at the Eduardo Mondlane University, and applied thesis work for public health trainees.

Conceptual Framework

Figure 2.2 shows a common conceptual framework, adapted from Bryce et al¹², used by all five countries selected to implement PHIT Partnership projects focused on health systems strengthening, as supported through the Doris Duke Charitable Foundation. Briefly, the Mozambique PHIT Partnership focused on governance, leadership, and financing to improve the following three WHO health system building blocks—(1) health information system; (2) human resources; and (3) medicines, equipment, and commodities—to ultimately improve child mortality through changes on coverage of essential maternal and child health services.

Inputs and Process			Outputs	Outcomes	Impact
Governance and leadership	Financing	Health information system	Intervention access and services readiness	Coverage of interventions	Mortality
		Human resources			
		Medicines, equipment, and commodities	Intervention quality		
Contextual factors, including non-health system determinants					

Figure 2.2. African Health Initiative common conceptual model. Adapted from Bryce et al¹⁰

Data Sources and Variables

To determine outputs and outcomes, we used indicators from repeated household surveys conducted between 2003 and 2016 (DHS 2003, DHS 2011, IMASIDA 2015, and INCOMAS 2016) to conduct time-series analyses to assess the community-level impact of the Mozambique PHIT Partnership on: (1) child mortality and (2) coverage and utilization of essential maternal and child health care services. Briefly,

each Demographic and Health Survey (DHS) and HIV/AIDS and Malaria Indicator Survey (Inquérito de Indicadores de Imunização, Malária e HIV/SIDA em Moçambique [IMASIDA]) is a multistage probability sampling of household clusters, which are located within 21 stratas (each province has two stratas for urban and rural areas, except Maputo City, which has one) and enumeration areas (a geographical demarcation for 10,000 to 20,000 households). Within each enumeration area, between 15 and 25 household clusters were randomly selected, and within each cluster, around 15-25 households were selected. Household response rates were above 90% in each of the four surveys. Mothers of children under the age of five were the primary sampling target^{21,26,27}. The 2016 Inquérito Comunitário em Manica e Sofala (INCOMAS) survey was designed to increment the sample size of the IMASIDA 2015 in Sofala (PHIT intervention site) and Manica (PHIT control site) provinces; however, it was conducted a year after the IMASIDA 2015 due to military instability and delayed ethical approval. Before the INCOMAS 2016 was conducted, satellite information using OpenStreet Maps were used to identify buildings, then random household clusters were chosen and approached for interviews, as reported elsewhere²⁸.

Data for covariates at the provincial level were collected from the 1997 and 2007 Mozambique Population and Housing Census to determine population projections and the Ministry of Health National Directorate of Human Resources statistics health-workforce data. Provincial-level shape files containing boundaries of the 11 provinces were obtained from Direcção Nacional de Geografia e Cadastro (DINAGECA), the national mapping agency in Mozambique.

Outcomes

Study outcomes include indicators covering the outcome and output domains of the impact evaluation plan, collected through household surveys. Outcome indicators focus on the continuum of maternal, newborn, and child health services available in household surveys (Table 2.1). All outcomes are assigned to a particular date (either the data of the survey or the last pregnancy), and they refer to the mother (last pregnancy) or to the child.

Table 2.1. Outcome indicators assessed to determine impact of PHIT Partnership project

Type	Outcome Indicator	Definition
Impact	Under-5 mortality rate* (${}_5q_0$)	Probability of death before the age of 60 months
Impact	Infant mortality rate (${}_1q_0$)	Probability of death before the age of 12 months
Outcome	Coverage of at least 4 antenatal care visits (ANC4+)	Proportion of women with at least 4 ANC visits during the last pregnancy which can be tracked using the child's date of birth
Outcome	Institutional deliveries (ID)	The proportion of women who delivered in a health facility among women who delivered in the 5 years prior to the survey
Outcome	Proportion of women receiving 2 or more doses of intermittent preventive treatment for malaria (IPTp2+)	Proportion of women receiving at least 2 doses of IPTp during the last pregnancy. Time is set to date of birth of the last child.
Outcome	Skilled birth attendance (SBA)	Proportion of women who delivered with a skilled birth attendant for the last pregnancy
Outcome	Cesarean section rate (Cesar)	Proportion of live births delivered by cesarean section
Outcome	Diphtheria, tetanus, and pertussis vaccine coverage (DTP3)	Proportion of children between the age of 12 and 23 months with some evidence of DTP3 vaccine
Outcome	Full immunization coverage (Fullimune)	Proportion of children between the age of 12 and 23 months with evidence of full vaccination
Outcome	Fever treatment (TxFever)	The proportion of children under 5 years of age with treatment for fever in the previous 2 weeks
Outcome	Acute respiratory infection treatment (TxARI)	Children with antibiotic treatment for acute respiratory infection in the previous 2 weeks
Outcome	Oral rehydration (TxDiar) for children with diarrhea	Children with oral rehydration during an episode of diarrhea in the previous 2 weeks

* Primary outcome

The predictor of interest for our analysis is the Mozambique PHIT Partnership intervention, represented by Sofala Province. The two comparators are Manica Province and “No Sofala” (defined as the average of all other provinces excluding Maputo City and Sofala). To identify covariates to adjust for, we identified WHO essential health system building block variables and conducted a literature review on child mortality, maternal and child health care utilization, and health systems strengthening^{29–32}. We also followed guidance for large-scale effectiveness evaluations³³. The covariates are presented in Table 2.2.

Table 2.2. Covariates (explanatory factors) included in the adjusted analysis

Covariate	Level	Definition
Health workforce density	Provincial	Number of physicians, nurses, midwives, medical assistants, and public health personnel per 10,000 people in each province per year.
Gross domestic product per capita	Provincial	Gross domestic product per province
Province	Provincial	This is the treatment variable. Dummy indicator for each of the 10 provinces.
Age	Mother	Quinquennial age categories from 15 to 49 years old. Alternatively, restricted cubic splines with nodes set at each quinquennium.
Education	Mother	Mother's level of education categorized as: none, primary (up to 7 years of education), and secondary or more (at least 8 years of education).
Marital status	Mother	Single, married or in union, widow or divorced
Age (months)	Child	
Wealth quintile	Household	Categorized
Place of residence	Household	Urban or rural
Calendar time	Calendar time	Period of intervention indicators and linear splines of calendar time

Statistical Analysis

Descriptive statistics including means (standard deviation [SD]), median (interquartile range [IQR]) and range for numeric variables, and frequencies (proportions) were used. For the impact analysis, we conducted two time-series analyses, uncontrolled and controlled. For the uncontrolled analysis, the goal was to compare changes to the outcome level within each province (i.e., Sofala, Manica, or No Sofala) between 2010 and 2015. This is presented both as absolute differences (AD) and proportion ratios (PR). For the controlled analysis, changes within Sofala Province are compared with changes within the comparators. This is presented as difference of proportion differences (DPD) and ratio of proportion ratios (RPR) between Sofala Province and either Manica Province or No Sofala.

Three approaches were used to estimate the impact measures. For the first approach, we direct estimates from DHS 2011 (as the baseline) and IMASIDA 2015 and INCOMAS 2016 (as the end of PHIT intervention. We estimated within each survey province-level coverages and mortality, accounting for the complex survey design through the use of sampling probability weights. Standard errors of these estimates

are based on the use of first-order Taylor linearization as implemented in the R survey library. We then produced estimates of AD, PR, DPD, and RPR at the province level and determined their 95% confidence intervals (95% CI) using the delta method. Although the intervention started almost a year before the DHS 2011, the DHS is considered to have captured baseline data because it includes information from five years prior to the survey. To estimate impact at the end of intervention, we averaged the province-level estimates if data from both the IMASIDA 2015 and the INCOMAS 2016 were available.

The second and third approaches estimate the impact measures through, respectively, unadjusted and adjusted random-effects logistic regression models with spatial components. Both models include (1) linear time segmented in 2010 so two-yearly trends pre-2010 and post-2010, (2) province-level random effects, and (3) spatial terms as expressed in the equation:

$$\log\left(\frac{p_{jcit}}{(1 - p_{jcit})}\right) = (\beta_0 + b_{0j} + b_{0c}) + (\beta_1 + b_{1j}) \cdot \text{timeSince2000} + (\beta_2 + b_{2j}) \cdot \text{post2010} + (\beta_3 + b_{3j}) \cdot \text{timeSince2010} + S_j + X_{\text{covariates}}\gamma$$

Where p is the proportion of each indicator at year t for province j , cluster c (the survey primary sample unit), and child i (or mother); timeSince2000 indicates the year of birth of the child index centered at 2000; timeSince2010 is either zero for children born before 2010 or the difference between a child's date of birth and January 2010; and post2010 is a dummy indicator to indicate a child born after 2010. The spatial term S_j acknowledges that a province j coverage is shared with neighbor provinces. The $X_{\text{covariates}}$ are added in the adjusted model and represent terms for household, mother, child, and province characteristics as indicated in table 2.2. The above model was also used for child mortality, whereby additional intercepts were included to reflect age-specific hazards (during the first month of life, between 2 and 12 months of age, and between 13 and 60 months of age) as a discrete survival analysis model. This regression is repeated for all 12 outcomes through Bayesian software modeling using the INLA (integrated nested Laplace approximation) method. The logistic regression produces odds ratios; however, in this analysis the impact measures of interest are AD, PR, DID, and RPR. To obtain these, we obtained 2,000 posterior realizations

of the beta parameters and used them to obtain predictions for 2010 and 2015. We then used the predictions to obtain the measure of impact of interest and their 95% credible interval (95% CrI).

Ethical Considerations

The datasets from DHS 2003, DHS 2011, and IMASIDA 2015 are publicly available from the DHS Program website (<https://dhsprogram.com/data/available-datasets.cfm>). We obtained permission to download the data upon request to the DHS Program. The INCOMAS 2016 survey was conducted after approval by the Institutional Review Board of the National Institute of Health in Mozambique ²⁶.

Results

General and Demographic Characteristics

Using the four surveys (DHS 2003, DHS 2011, IMASIDA 2015, and INCOMAS 2016), we included data for a total of 18,733 mothers and their 26,140 children in the analysis, with the surveys since 2011 accounting for 68.3% (12,799) of mothers and 70.8% (18,514) of children. However, different numbers of observations are included for each outcome (Table 2.3), with far fewer observations on child health care utilization (fever, acute respiratory treatment, and oral rehydration). Due to spasticity, we did not conduct any modeling for treatment of acute respiratory infection.

In 2010, Manica and Sofala provinces had similar population sizes (1.61 million and 1.81 million, respectively). They also had similar numbers of women of reproductive age (WRA; ages 15 to 49) (0.37 million and 0.42 million, respectively) and children under the age of five years (0.31 million and 0.32 million, respectively). However, Sofala had a higher proportion of WRA living in urban areas than Manica (40.5% versus 25.6%) and a higher density of health care providers and GDP per capita (Table 2.4).

Table 2.3. Number of children and their mothers, and number of observations by indicator and survey

Indicator	Survey				Total
	DHS 2003	DHS 2011	IMASIDA 2015	INCOMAS 2016	
Mothers	5934	6954	3540	2305	18733
Children	7626	10279	4896	3339	26140
ANC4+	5878	6871	3562	2800	19111
IPTp2+	0	4427	2029	0	10976
SBA	7626	10279	4896	3201	36572
ID	7615	10279	2683	0	27297
Cesar	7624	10279	0	1963	19866
DTP3	1735	2050	984	718	7724
Fullimune	1733	2050	984	718	7722
TxFever	1862	1238	1241	829	7630
TxARI	662	149	260	47	1601
TxDiar	982	997	524	753	5105
₁ q ₀ and ₅ q ₀	7626	10279	4896	0	22801

Note: Maputo City was excluded from this analysis.

Abbreviations: ₁q₀, infant mortality rate; ₅q₀, under-5 mortality rate; ANC4+, at least four antenatal care visits; Cesar, cesarean section rate; DHS, Demographic and Health Survey; DTP3, coverage of diphtheria, tetanus, and pertussis combined vaccine; Fullimune, full immunization coverage; ID, institutional deliveries; IMASIDA, Inquérito de Indicadores de Imunização, Malária e HIV/SIDA em Moçambique; INCOMAS, Inquérito Comunitário em Manica e Sofala; IPTp2+, at least two doses of intermittent preventive treatment of malaria in pregnant women; TxDiar, oral rehydration; SBA, skilled birth attendance; TxARI, acute respiratory infection treatment; TxFever; fever treatment.

Table 2.4. Province characteristics in 2010

Province	Population in 2010 (millions)	WRA in 2010 (millions)	Children under 5 in 2010 (millions)	% of urban WRA	GDP per capita in 2010 (USD)	Health worker density per 100,000 hab	Physician density per 100,000 hab	MCH nurse density in 2010 per 100,000 hab	Women literacy (%)
Niassa	1.36	0.32	0.26	23.9	238.8	65.0	2.0	53.0	23
Cabo Delgado	1.73	0.41	0.30	23.4	290.0	63.0	2.2	50.4	17
Nampula	4.41	1.05	0.77	30.7	356.2	52.5	1.7	42.6	24
Zambezia	4.21	1.00	0.80	19.6	236.7	49.6	1.3	25.3	22
Tete	2.05	0.46	0.40	14.9	280.7	46.9	1.9	33.5	33
Manica	1.61	0.37	0.31	25.6	248.0	55.8	2.1	41.2	40
Sofala	1.81	0.42	0.32	40.5	603.4	72.9	3.8	53.7	37
Inhambane	1.38	0.34	0.23	26.0	609.4	86.2	2.2	71.4	48
Gaza	1.30	0.32	0.22	28.7	394.7	64.5	3.0	40.8	45
Maputo Province	1.39	0.37	0.20	72.7	1214.7	53.6	3.0	37.4	66
Maputo City	1.16	0.34	0.14	100.0	1677.6	157.6	31.2	86.3	85
Average*	2.13	0.51	0.39	28.1	429.9 [†]	59.7 [†]	2.2 [†]	43.9 [†]	35

Abbreviations: GDP, gross domestic product; hab, habitants; MCH, maternal and child health; WRA, women of reproductive age.

* The averages do not include Sofala and Maputo City provinces.

[†] Geometric mean

Health System Outputs

Mother Care Services

Antenatal care coverage (at least four visits; ANC4+) in 2011 was estimated to be 76.0%, 55.1%, and 49.8%, respectively, in Manica, Sofala, and No Sofala. From 2011 to 2015, it changed -16.8% (95% CI, -30.1% to -3.4%), 5.0% (95% CI, -8.9% to 19.0%), and 5.4% (95% CI, -2.9% to 13.7%), respectively (Table 2.5 and Figure 2.3). Therefore, Sofala gained 21.8% (95% CI, 2.5% to 41.1%) compared with Manica; whereas, it had similar gains compared with other provinces (DPD, -0.4%; 95% CI, -16.6% to 15.9%) (Figure 2.4). Similarly, in the multiplicative changes, Sofala gained further 40% (RPR, 1.40; 95% CI, 1.20 to 1.63) in the relative change coverage compared with Manica, but it did not change substantially (RPR, 0.98; 95% CI, 0.85 to 1.14) compared with other provinces together (Figures 5 and 6). The model-based estimates are of the same strength, although the 95% credible interval is shorter but not enough to change the statistical significance (Table 2.6 and Table 2.7) (Figures 2.3, 2.4, 2.5 and 2.6).

Both Manica and Sofala had similar levels of IPTp2+ (at least two doses of intermittent preventive treatment for malaria) coverage in 2011 (31.5% and 30.1%), which was almost the double the level of coverage compared with other provinces combined (17.8%). Sofala gained 21.6%, a statistically significant AD (21.6%; 95% CI, 6.1% to 37.2%), whereas Manica did not change meaningfully (AD, -1.3; 95% CI, -35.0% to 32.4%), and the other provinces combined gained a statistically significant 15.8% (95% CI, 5.6% to 25.9%). Therefore, using survey design analysis, Sofala made additional gains compared with Manica a statistically non-significant 22.9% (95% CI, -14.2% to 60.0%) (Table 2.5 and Figures 2.3 and 2.4). The model-based estimates are similar in strength although more precise (adjusted DPD, 20.1%; 95% CrI, 4.6% to 38.0%) (Table 2.7 and Table 2.8, and Figure 2.4). Compared with other provinces, Sofala gained 5.8% (95% CI, -12.7% to 24.4%), a statistically non-significant increment (Table 5) and similar magnitude gains were observed in the model-based estimates (Table 7 and Table 8). In the multiplicative scale, Sofala gained 1.79 (RPR, 1.79; 95% CI, 1.04 to 3.08) times more compared with Manica, and 9% (RPR, 0.91; 95% CI,

0.71 to 1.16) less, although not statistically different from null, compared with other provinces (Figure 2.5 and Figure 2.6).

From 2011 to 2016, the proportion of women who had institutional deliveries by cesarean section increased 0.7% (95% CI, -13.6% to 14.9%) in Manica and 2.4% (95% CI, -10.8% to 15.6%); however, these changes are not statistically significant different from null (Table 5). Moreover, the cesarian section rates in Manica (4.8%) and Sofala (8.4%) were still far from the WHO recommendation of 15%. In 2011, both Manica and Sofala had higher rates of skilled birth attendance (76.3% and 72.9%) compared with No Sofala (Table 5). Between 2011 and 2015, skilled birth attendance decreased 1.5% in Manica (AD, -1.5%; 95% CI, -29.8% to 26.7%) and increased 15.0% (AD, 15.0%; 95% CI, -11.5% to 41.6%) in Sofala; however, this change was not statistically significant (Figure 2.3). Although Sofala gained 16.6% (DPD, 16.6%; 95% CI, -22.2% to 55.3%) compared with Manica, the confidence interval still includes the null (Table 5). The model-based analysis (Table 2.6 and Table 2.7) indicates that the additional gain in Sofala was 6.6% (95% CrI, -0.5% to 14.3%) compared with Manica. Nevertheless, gains in skilled birth attendance rates compared with the average of 9 provinces are in a negative direction although not statistically significant (Table 2.6 and Table 2.7, and Figures 2.3 to 2.6).

Childcare Services—Immunization and Treatment Care Seeking

According to DHS 2011 survey estimates, the number of children ages 12 to 23 months who received three doses of the DTP vaccine (DTP3) in Manica, Sofala, and other provinces, respectively, was 77.5%, 85.6%, and 75.4% (Table 2.5). Compared with the IMASIDA 2015 and INCOMAS 2016, all provinces showed improvements in DTP3 coverage, except Sofala, which decreased by 1.8% (AD, -1.8%; 95% CI, -24.0% to 20.4%). However, model-adjusted estimates indicate gains in all provinces, with Sofala showing fewer gains compared with Manica (DPD, -2.5%; 95% CrI, -8.5% to 1.3%) and other provinces (DPD, -1.8%; 95% CrI, -5.7% to 1.2%) (Table 2.7 and Figures 2.3 to 2.6).

The proportion of children under the age of five with fever who received antimalarial treatment was high in Sofala (75.3%) in 2011 compared with Manica (52.7%) and other provinces (52.9%) (Table 5). However, in the following years, this indicator showed a slight decrease in Sofala, although the change was

not statistically significant. Manica Province showed improvements by 1.34 (PR: 1.34; 95% CI, 1.04 to 1.72), 1.31 (PR: 1.31; 95% CI, 1.10 to 1.59), and 1.15 (PR: 1.15; 95% CI, 0.98 to 1.25) times in non-modeled, unadjusted modeled, and adjusted modeled analyses, respectively.

Health System Outcomes

Child Mortality

The infant mortality rates (${}_1q_0$) in 2011 for Manica and Sofala provinces were 50.4 and 58.8 per 1,000 live births, respectively, whereas the child mortality rates (${}_5q_0$) were 80.4 and 71.8 per 1,000 live births. Both model-based estimates indicate substantial reductions of at least 40% of the levels observed in 2010 within the provinces for both infant (${}_1q_0$) and child (${}_5q_0$) mortality between 2010 and 2015 (Table 7 and Table 8). However, Sofala did not have mortality drop beyond other provinces showed during this period (Figures 2.3 to 2.6).

Table 2.5. Direct survey estimates of health service coverage (in percentage) and mortality (per 1000 live births) – point estimates and 95% confidence interval in brackets

Indicator	Province [†]	Survey Coverage			Absolute	Difference in Proportion	Proportion	Ratio of Proportion
		DHS 2011	IMASIDA 2015	INCOMAS 2016	Difference	Differences	Ratio	Ratios
Mother Care Services								
ANC4+	Manica	76.0 (71.8 to 79.8)	46.0 (37.2 to 55.1)	71.2 (68.6 to 73.7)	-16.8 (-30.1 to -3.4)	21.8 (2.5 to 41.1)	0.78 (0.71 to 0.86)	1.40 (1.20 to 1.63)
ANC4+	Sofala	55.1 (49.5 to 60.5)	50.2 (42.4 to 58.1)	69.2 (66.3 to 72.0)	5.0 (-8.9 to 19.0)	-	1.09 (0.97 to 1.23)	-
ANC4+	No Sofala	49.8 (47.6 to 51.9)	55.2 (51.6 to 58.7)	-	5.4 (-2.9 to 13.7)	-0.4 (-16.6 to 15.9)	1.11 (1.03 to 1.20)	0.98 (0.85 to 1.14)
IPTp2+	Manica	31.5 (26.4 to 37.1)	30.2 (17.8 to 46.3)	-	-1.3 (-35.0 to 32.4)	22.9 (-14.2 to 60.0)	0.96 (0.58 to 1.60)	1.79 (1.04 to 3.08)
IPTp2+	Sofala	30.1 (26.2 to 34.4)	51.7 (45.4 to 58.0)	-	21.6 (6.1 to 37.2)	-	1.72 (1.43 to 2.06)	-
IPTp2+	No Sofala	17.8 (16.0 to 19.7)	33.5 (29.5 to 37.9)	-	15.8 (5.6 to 25.9)	5.8 (-12.7 to 24.4)	1.89 (1.61 to 2.22)	0.91 (0.71 to 1.16)
Cesar	Manica	4.1 (2.2 to 7.5)	-	4.8 (3.6 to 6.3)	0.7 (-13.6 to 14.9)	1.7 (-17.6 to 21.1)	1.16 (0.59 to 2.29)	1.20 (0.52 to 2.76)
Cesar	Sofala	6.0 (4.1 to 8.6)	-	8.4 (6.2 to 11.4)	2.4 (-10.8 to 15.6)	-	1.40 (0.87 to 2.26)	-
Cesar	No Sofala	3.3 (2.9 to 3.9)	-	-	-	-	-	-
SBA	Manica	76.3 (69.0 to 82.3)	74.8 (63.3 to 83.6)	56.8 (53.7 to 59.9) *	-1.5 (-29.8 to 26.7)	16.6 (-22.2 to 55.3)	0.98 (0.83 to 1.15)	1.23 (1.01 to 1.51)
SBA	Sofala	72.9 (66.0 to 78.9)	88.0 (78.7 to 93.5)	58.5 (54.4 to 62.4) *	15.0 (-11.5 to 41.6)	-	1.21 (1.07 to 1.36)	-
SBA	No Sofala	52.6 (49.4 to 55.8)	69.9 (65.7 to 73.8)	-	17.3 (6.4 to 28.2)	-2.3 (-31.0 to 26.4)	1.33 (1.22 to 1.45)	0.91 (0.78 to 1.05)
ID	Manica	75.3 (68.6 to 81.0)	73.0 (62.1 to 81.6)	79.7 (77.1 to 82.1) *	-2.4 (-28.8 to 24.1)	16.0 (-25.2 to 57.1)	0.97 (0.83 to 1.14)	1.22 (0.99 to 1.51)
ID	Sofala	73.4 (66.4 to 79.4)	87.0 (74.5 to 93.8)	55.4 (51.8 to 58.9) *	13.6 (-17.9 to 45.1)	-	1.19 (1.03 to 1.36)	-
ID	No Sofala	51.2 (48.1 to 54.2)	66.8 (62.6 to 70.7)	-	15.6 (5.0 to 26.2)	-2.0 (-35.2 to 31.2)	1.30 (1.20 to 1.42)	0.91 (0.77 to 1.07)
Childcare services								
DTP3	Manica	77.5 (70.6 to 83.1)	90.8 (80.8 to 95.8)	82.7 (78.1 to 86.4)	9.8 (-11.4 to 31.0)	-11.6 (-42.3 to 19.1)	1.13 (1.02 to 1.24)	0.87 (0.76 to 1.00)
DTP3	Sofala	85.6 (77.4 to 91.1)	82.9 (74.5 to 88.9)	84.6 (80.0 to 88.3)	-1.8 (-24.0 to 20.4)	-	0.98 (0.89 to 1.07)	-
DTP3	No Sofala	75.4 (72.2 to 78.4)	81.7 (76.4 to 86.0)	-	6.2 (-8.1 to 20.6)	-8.0 (-34.5 to 18.4)	1.08 (1.01 to 1.16)	0.90 (0.80 to 1.02)
Fullimune	Manica	65.1 (57.4 to 72.1)	65.8 (52.0 to 77.4)	62.6 (57.4 to 67.6)	-0.9 (-22.3 to 20.6)	-10.2 (-43.0 to 22.6)	0.99 (0.84 to 1.16)	0.87 (0.70 to 1.08)
Fullimune	Sofala	78.7 (69.0 to 86.0)	69.1 (56.9 to 79.2)	66.0 (60.3 to 71.3)	-11.1 (-35.9 to 13.8)	-	0.86 (0.74 to 0.99)	-
Fullimune	No Sofala	62.6 (58.9 to 66.2)	65.6 (60.7 to 70.1)	-	3.0 (-9.5 to 15.4)	-14.0 (-41.8 to 13.7)	1.05 (0.95 to 1.15)	0.82 (0.69 to 0.97)
TxFever	Manica	52.7 (40.2 to 64.8)	68.4 (57.4 to 77.7)	72.4 (67.3 to 76.9)	17.8 (-10.2 to 45.7)	-26.1 (-61.9 to 9.6)	1.34 (1.04 to 1.72)	0.66 (0.50 to 0.89)
TxFever	Sofala	75.3 (66.9 to 82.1)	70.2 (57.9 to 80.2)	63.4 (58.2 to 68.4)	-8.4 (-30.7 to 14.0)	-	0.89 (0.77 to 1.02)	-
TxFever	No Sofala	52.9 (48.5 to 57.4)	59.0 (54.4 to 63.4)	-	6.0 (-6.7 to 18.8)	-14.4 (-40.1 to 11.3)	1.11 (0.99 to 1.25)	0.80 (0.67 to 0.96)

TxARI	Manica	15.2 (3.1 to 50.3)	75.1 (45.5 to 91.6)	70.9 (41.3 to 89.4)	57.9 (-15.9 to 131.7)	-39.6 (-138.5 to 59.2)	4.81 (1.08 to 21.36)	0.28 (0.06 to 1.37)
TxARI	Sofala	54.4 (27.1 to 79.3)	68.6 (43.9 to 85.9)	76.3 (56.1 to 89.1)	18.2 (-47.5 to 84.0)	-	1.34 (0.76 to 2.35)	-
TxARI	No Sofala	49.9 (39.5 to 60.2)	59.6 (50.3 to 68.2)	-	9.7 (-18.2 to 37.6)	8.6 (-62.9 to 80.0)	1.19 (0.92 to 1.55)	1.12 (0.60 to 2.08)
Orreh	Manica	74.3 (62.8 to 83.2)	71.1 (47.6 to 86.9)	67.1 (61.9 to 72.0)	-5.2 (-38.5 to 28.1)	-7.5 (-47.7 to 32.8)	0.93 (0.75 to 1.15)	0.90 (0.70 to 1.16)
Orreh	Sofala	78.1 (70.4 to 84.2)	59.9 (45.5 to 72.8)	70.6 (65.1 to 75.5)	-12.6 (-35.2 to 9.9)	-	0.84 (0.73 to 0.97)	-
Orreh	No Sofala	58.7 (53.7 to 63.5)	52.3 (45.9 to 58.7)	-	-6.4 (-22.7 to 9.8)	-6.2 (-34.1 to 21.6)	0.89 (0.77 to 1.03)	0.94 (0.77 to 1.15)
Child mortality								
1q0 [†]	Manica	50.4 (38.4 to 66.2)	18.2 (8.6 to 38.8)	-	-32.2 (-153.1 to 88.7)	-13.8 (-177.4 to 149.7)	0.36 (0.16 to 0.81)	0.78 (0.27 to 2.20)
1q0 [†]	Sofala	64.0 (48.0 to 85.4)	18.0 (9.9 to 32.5)	-	-46.0 (-156.2 to 64.1)	-	0.28 (0.15 to 0.54)	-
1q0 [†]	No Sofala	58.8 (52.7 to 65.6)	24.6 (18.9 to 32.0)	-	-34.2 (-84.1 to 15.8)	-11.9 (-132.9 to 109.1)	0.42 (0.32 to 0.56)	0.67 (0.33 to 1.37)
5q0 [†]	Manica	80.4 (54.2 to 119.3)	40.2 (12.8 to 125.9)	-	-40.3 (-303.9 to 223.3)	-10.9 (-297.9 to 276.1)	0.50 (0.15 to 1.69)	0.58 (0.14 to 2.30)
5q0 [†]	Sofala	71.8 (55.3 to 93.2)	20.6 (11.3 to 37.6)	-	-51.2 (-164.6 to 62.3)	-	0.29 (0.15 to 0.55)	-
5q0 [†]	No Sofala	69.1 (62.8 to 76.1)	30.3 (23.8 to 38.5)	-	-38.9 (-88.8 to 11.1)	-12.3 (-136.3 to 111.6)	0.44 (0.34 to 0.57)	0.66 (0.32 to 1.33)

* The INCOMAS 2016 indicator was not used to compute these trends.

[†] Per 1,000 per live births.

[‡] No Sofala indicates other provinces excluding Maputo City.

Abbreviations: 1q0, infant mortality rate; 5q0, under-5 mortality rate; ANC4+, at least four antenatal care visits; Cesar, cesarean section rate; DHS, Demographic and Health Survey; DTP3, coverage of diphtheria, tetanus, and pertussis combined vaccine; Fullimune, full immunization coverage; ID, institutional deliveries; IMASIDA, Inquérito de Indicadores de Imunização, Malária e HIV/SIDA em Moçambique; INCOMAS, Inquérito Comunitário em Manica e Sofala; IPTp2+, at least two doses of intermittent preventive treatment of malaria in pregnant women; SBA, skilled birth attendance; TxARI, acute respiratory infection treatment; TxDiar, diarrhea treatment; TxFever, fever treatment.

Table 2.6. Unadjusted model-based estimates of health service coverage (in percentage) and mortality (per 1000 live births) – point estimates and 95% credible interval in brackets

Indicator	Province [‡]	Model Unadjusted Coverage (%)		Absolute difference	Difference in proportion Differences	Proportion Ratio	Ratio of Proportion Ratios
		2010	2015				
Mother Care Services							
ANC4+	Manica	72.1 (67.6 to 76.6)	70.6 (68.5 to 72.7)	-1.5 (-6.3 to 3.7)	18.7 (11.9 to 26.1)	0.98 (0.92 to 1.05)	1.34 (1.20 to 1.51)
ANC4+	Sofala	55.7 (50.9 to 60.4)	72.9 (70.5 to 75.2)	17.3 (12.0 to 22.4)	-	1.31 (1.20 to 1.44)	-
ANC4+	No Sofala	49.7 (47.4 to 52.1)	64.9 (61.9 to 67.8)	15.2 (10.9 to 19.3)	2.1 (-4.2 to 8.2)	1.31 (1.21 to 1.40)	1.01 (0.90 to 1.12)
IPTp2+	Manica	28.5 (22.0 to 36.1)	28.2 (19.8 to 37.6)	-0.3 (-12.3 to 12.0)	29.5 (12.2 to 47.0)	1.01 (0.63 to 1.49)	2.18 (1.26 to 3.58)
IPTp2+	Sofala	27.6 (21.6 to 33.9)	56.8 (47.2 to 66.2)	29.2 (16.6 to 41.4)	-	2.09 (1.52 to 2.79)	-
IPTp2+	No Sofala	16.0 (14.2 to 17.8)	34.5 (31.3 to 37.7)	18.5 (14.3 to 22.5)	10.7 (-2.2 to 23.0)	2.16 (1.83 to 2.53)	0.97 (0.69 to 1.31)
ID	Manica	81.4 (77.7 to 84.6)	83.7 (81.6 to 85.5)	2.3 (-1.0 to 5.6)	1.0 (-4.2 to 5.6)	1.03 (0.99 to 1.07)	1.02 (0.95 to 1.09)
ID	Sofala	67.9 (63.4 to 72.7)	71.2 (68.5 to 73.5)	3.3 (-1.4 to 7.6)	-	1.05 (0.98 to 1.12)	-
ID	No Sofala	66.8 (64.0 to 69.6)	73.2 (70.1 to 76.6)	6.3 (2.2 to 11.3)	-3.0 (-10.3 to 1.6)	1.10 (1.03 to 1.18)	0.96 (0.86 to 1.03)
SBA	Manica	71.0 (66.2 to 75.6)	66.4 (63.4 to 69.1)	-4.6 (-8.9 to -0.0)	8.0 (1.6 to 14.1)	0.94 (0.88 to 1.00)	1.12 (1.03 to 1.23)
SBA	Sofala	69.5 (64.2 to 74.4)	72.9 (69.9 to 75.4)	3.4 (-1.8 to 8.6)	-	1.05 (0.98 to 1.13)	-
SBA	No Sofala	64.6 (61.7 to 67.2)	74.5 (71.3 to 77.5)	9.9 (5.2 to 14.5)	-6.5 (-13.2 to -0.3)	1.15 (1.08 to 1.23)	0.91 (0.83 to 0.99)
cesar	Manica	2.8 (1.9 to 4.0)	6.3 (4.9 to 8.0)	3.5 (1.9 to 5.1)	3.5 (1.4 to 6.0)	2.29 (1.56 to 3.29)	1.16 (0.94 to 1.42)
cesar	Sofala	4.4 (3.1 to 6.0)	11.4 (8.8 to 14.5)	7.0 (4.3 to 10.1)	-	2.63 (1.83 to 3.72)	-
cesar	No Sofala	-	-	-	-	-	-
Childcare services							
DTP3	Manica	78.8 (73.4 to 83.6)	85.2 (82.2 to 87.9)	6.4 (2.1 to 11.1)	-0.7 (-3.7 to 2.0)	1.08 (1.03 to 1.15)	0.99 (0.95 to 1.02)
DTP3	Sofala	83.0 (78.1 to 87.2)	88.6 (85.9 to 90.9)	5.6 (2.0 to 10.0)	-	1.07 (1.02 to 1.13)	-
DTP3	No Sofala	81.6 (78.9 to 84.1)	87.5 (85.1 to 89.6)	5.9 (2.6 to 9.1)	-0.2 (-2.3 to 1.8)	1.07 (1.03 to 1.11)	1.00 (0.97 to 1.02)
Fullimmune	Manica	63.5 (56.9 to 69.4)	65.4 (61.2 to 69.2)	1.9 (-3.6 to 7.6)	0.7 (-2.7 to 3.9)	1.03 (0.95 to 1.13)	1.01 (0.95 to 1.06)
Fullimmune	Sofala	70.4 (64.7 to 75.8)	73.1 (69.0 to 77.0)	2.6 (-2.5 to 8.0)	-	1.04 (0.97 to 1.12)	-
Fullimmune	No Sofala	68.8 (65.7 to 71.7)	71.4 (67.9 to 74.7)	2.7 (-2.0 to 7.3)	-0.0 (-3.2 to 2.3)	1.04 (0.97 to 1.11)	1.00 (0.96 to 1.03)
TxFever	Manica	57.3 (47.3 to 67.0)	74.5 (69.8 to 78.7)	17.2 (6.6 to 28.3)	-20.9 (-35.4 to -7.3)	1.31 (1.10 to 1.59)	0.73 (0.58 to 0.90)
TxFever	Sofala	73.4 (64.9 to 80.8)	69.6 (64.9 to 74.0)	-3.7 (-12.7 to 5.5)	-	0.95 (0.84 to 1.08)	-
TxFever	No Sofala	54.7 (49.0 to 59.9)	68.0 (62.1 to 73.6)	13.3 (4.7 to 21.5)	-17.1 (-29.5 to -4.6)	1.25 (1.08 to 1.43)	0.77 (0.63 to 0.92)

TxARI	Manica	50.1 (37.3 to 63.1)	72.0 (60.8 to 81.9)	21.9 (5.8 to 37.4)	1.0 (-2.0 to 4.5)	1.46 (1.09 to 1.96)	1.00 (0.94 to 1.06)
TxARI	Sofala	51.8 (39.1 to 65.1)	74.7 (64.3 to 83.5)	22.9 (7.3 to 38.0)	-	1.47 (1.12 to 1.93)	-
TxARI	No Sofala	50.2 (38.2 to 62.0)	72.7 (63.2 to 81.2)	22.5 (6.5 to 37.8)	0.4 (-1.7 to 3.0)	1.47 (1.11 to 1.95)	1.00 (0.95 to 1.04)
Orreh	Manica	68.9 (62.6 to 74.9)	68.9 (64.8 to 73.0)	-0.0 (-5.7 to 6.2)	-1.5 (-6.1 to 2.6)	1.00 (0.92 to 1.10)	0.98 (0.92 to 1.04)
Orreh	Sofala	75.2 (69.6 to 80.2)	73.7 (69.9 to 77.6)	-1.5 (-7.0 to 4.2)	-	0.98 (0.91 to 1.06)	-
Orreh	No Sofala	60.0 (54.9 to 64.8)	54.8 (48.7 to 61.0)	-5.1 (-13.1 to 2.8)	3.6 (-0.9 to 8.5)	0.92 (0.79 to 1.05)	1.07 (0.98 to 1.18)
Child mortality							
1q0 [†]	Manica	41.7 (31.7 to 53.8)	18.0 (11.6 to 26.5)	-23.7 (-35.6 to -13.0)	-2.6 (-9.4 to 3.0)	0.44 (0.29 to 0.63)	1.11 (0.92 to 1.35)
1q0 [†]	Sofala	50.3 (39.1 to 64.0)	24.0 (15.9 to 34.3)	-26.3 (-39.8 to -13.0)	-	0.48 (0.32 to 0.71)	-
1q0 [†]	No Sofala	46.3 (38.7 to 55.1)	21.4 (16.3 to 27.9)	-24.9 (-36.5 to -13.2)	-1.4 (-6.4 to 2.8)	0.47 (0.32 to 0.68)	1.03 (0.89 to 1.18)
5q0 [†]	Manica	60.3 (46.9 to 76.5)	31.7 (20.8 to 46.0)	-28.6 (-45.5 to -12.9)	-0.6 (-8.6 to 7.0)	0.53 (0.36 to 0.76)	1.03 (0.84 to 1.28)
5q0 [†]	Sofala	63.6 (50.4 to 79.9)	34.4 (23.3 to 49.2)	-29.2 (-46.9 to -11.8)	-	0.55 (0.36 to 0.80)	-
5q0 [†]	No Sofala	60.1 (50.2 to 70.9)	32.1 (24.3 to 41.7)	-28.0 (-43.5 to -12.8)	-1.2 (-7.3 to 4.4)	0.54 (0.37 to 0.76)	1.01 (0.87 to 1.18)

* The INCOMAS 2016 indicator was not used to compute these trends.

[†] Per 1,000 live births.

[‡] No Sofala indicates other provinces excluding Maputo City.

Abbreviations: 1q0, infant mortality rate; 5q0, under-5 mortality rate; ANC4+, at least four antenatal care visits; Cesar, cesarean section rate; DHS, Demographic and Health Survey; DTP3, coverage of diphtheria, tetanus, and pertussis combined vaccine; Fullimune, full immunization coverage; ID, institutional deliveries; IMASIDA, Inquérito de Indicadores de Imunização, Malária e HIV/SIDA em Moçambique; INCOMAS, Inquérito Comunitário em Manica e Sofala; IPTp2+, at least two doses of intermittent preventive treatment of malaria in pregnant women; SBA, skilled birth attendance; TxARI, acute respiratory infection treatment; TxDiar, diarrhea treatment; TxFever, fever treatment.

Table 2.7. Adjusted model-based estimates of health service coverage (in percentage) and mortality (per 1000 live births) – point estimates and 95% credible interval in brackets

Indicator	Province [‡]	Model Adjusted Coverage (%)		Absolute difference	Difference in proportion	Proportion Ratio	Ratio of Proportion
		2010	2015		Differences		Ratios
Mother Care Services							
ANC4+	Manica	73.8 (66.7 to 80.2)	67.1 (60.6 to 73.1)	-6.8 (-12.3 to -1.3)	18.7 (11.5 to 26.0)	0.91 (0.84 to 0.98)	1.39 (1.21 to 1.61)
ANC4+	Sofala	45.6 (36.3 to 55.4)	57.5 (47.2 to 67.1)	11.9 (5.4 to 18.4)	-	1.27 (1.11 to 1.46)	-
ANC4+	No Sofala	48.5 (42.2 to 54.5)	59.9 (52.6 to 66.6)	11.4 (6.7 to 16.0)	0.6 (-6.7 to 7.5)	1.24 (1.13 to 1.34)	1.03 (0.89 to 1.18)
IPTp2+	Manica	33.6 (22.7 to 46.0)	24.8 (14.3 to 37.2)	-8.9 (-20.8 to 3.3)	20.2 (4.7 to 36.7)	0.75 (0.45 to 1.12)	2.39 (1.23 to 4.28)
IPTp2+	Sofala	17.1 (9.4 to 27.3)	28.4 (15.1 to 44.8)	11.3 (1.2 to 24.1)	-	1.70 (1.07 to 2.60)	-
IPTp2+	No Sofala	15.3 (10.5 to 20.6)	27.6 (19.4 to 37.2)	12.3 (7.6 to 18.2)	-1.0 (-11.6 to 10.7)	1.82 (1.53 to 2.19)	0.94 (0.58 to 1.45)
Institutional Deliveries	Manica	75.5 (66.5 to 83.0)	80.6 (71.1 to 88.1)	5.1 (-2.5 to 12.0)	4.5 (-4.2 to 13.5)	1.07 (0.97 to 1.17)	1.06 (0.95 to 1.19)
Institutional Deliveries	Sofala	73.7 (63.6 to 82.5)	83.3 (73.0 to 91.4)	9.6 (2.3 to 16.8)	-	1.13 (1.03 to 1.25)	-
Institutional Deliveries	No Sofala	64.5 (57.5 to 70.8)	72.3 (64.9 to 78.6)	7.8 (1.9 to 13.4)	1.7 (-5.0 to 8.2)	1.12 (1.03 to 1.22)	1.01 (0.92 to 1.10)
SBA	Manica	68.6 (59.6 to 76.6)	66.2 (58.3 to 73.5)	-2.5 (-8.4 to 3.7)	6.6 (-0.5 to 14.3)	0.97 (0.89 to 1.06)	1.10 (0.99 to 1.24)
SBA	Sofala	66.7 (56.5 to 75.7)	70.8 (61.4 to 79.7)	4.2 (-2.3 to 11.1)	-	1.06 (0.97 to 1.18)	-
SBA	No Sofala	60.6 (54.1 to 67.0)	70.6 (63.9 to 76.8)	10.0 (4.6 to 15.2)	-5.8 (-13.8 to 2.3)	1.17 (1.07 to 1.27)	0.91 (0.81 to 1.03)
Cesareans	Manica	1.3 (0.6 to 2.3)	2.7 (1.3 to 5.2)	1.5 (0.4 to 3.2)	0.4 (-0.3 to 1.5)	2.25 (1.37 to 3.45)	1.08 (0.92 to 1.27)
Cesareans	Sofala	1.4 (0.7 to 2.4)	3.2 (1.5 to 6.0)	1.9 (0.6 to 4.1)	-	2.44 (1.47 to 3.83)	-
Cesareans	No Sofala	-	-	-	-	-	-
Childcare services							
DTP3	Manica	80.6 (67.5 to 90.5)	89.5 (81.6 to 94.8)	8.9 (2.2 to 17.6)	-2.5 (-8.5 to 1.3)	1.11 (1.02 to 1.26)	0.97 (0.89 to 1.02)
DTP3	Sofala	86.1 (75.3 to 93.6)	92.4 (84.4 to 97.2)	6.3 (1.8 to 12.3)	-	1.08 (1.02 to 1.16)	-
DTP3	No Sofala	81.7 (71.6 to 89.4)	89.9 (83.6 to 94.6)	8.2 (2.4 to 14.9)	-1.8 (-5.7 to 1.2)	1.10 (1.03 to 1.20)	0.98 (0.93 to 1.02)
Full immunization	Manica	69.3 (55.6 to 80.7)	75.0 (63.2 to 84.7)	5.7 (-2.2 to 14.2)	-2.0 (-7.2 to 2.3)	1.09 (0.97 to 1.25)	0.97 (0.88 to 1.03)
Full immunization	Sofala	79.1 (66.5 to 88.8)	82.9 (69.2 to 92.2)	3.7 (-2.8 to 10.0)	-	1.05 (0.96 to 1.14)	-
Full immunization	No Sofala	70.2 (59.0 to 79.9)	75.3 (64.5 to 84.0)	5.2 (-2.3 to 12.3)	-1.4 (-5.0 to 2.4)	1.08 (0.97 to 1.20)	0.98 (0.92 to 1.03)
TxFever	Manica	63.7 (51.4 to 74.8)	72.6 (59.7 to 82.6)	8.9 (-1.1 to 19.8)	-15.4 (-26.5 to -5.5)	1.15 (0.98 to 1.36)	0.80 (0.66 to 0.93)
TxFever	Sofala	74.9 (62.0 to 84.1)	68.4 (53.1 to 80.2)	-6.5 (-17.4 to 3.7)	-	0.91 (0.76 to 1.05)	-

TxFever	No Sofala	59.9 (49.0 to 70.2)	70.5 (60.1 to 79.3)	10.6 (2.0 to 19.1)	-17.1 (-29.7 to -5.4)	1.18 (1.03 to 1.36)	0.78 (0.63 to 0.92)
TxARI	Manica	-	-	-	-	-	-
TxARI	Sofala	-	-	-	-	-	-
TxARI	No Sofala	-	-	-	-	-	-
Orreh	Manica	65.9 (54.1 to 77.1)	54.6 (40.9 to 69.1)	-11.3 (-20.4 to -2.2)	-0.7 (-4.8 to 3.0)	0.83 (0.69 to 0.96)	0.99 (0.90 to 1.07)
Orreh	Sofala	65.2 (53.4 to 75.8)	53.3 (39.4 to 68.5)	-12.0 (-21.5 to -2.7)	-	0.82 (0.67 to 0.96)	-
Orreh	No Sofala	61.2 (49.3 to 71.8)	47.2 (35.6 to 58.3)	-14.0 (-22.6 to -5.3)	2.1 (-1.8 to 6.6)	0.77 (0.64 to 0.91)	1.06 (0.96 to 1.18)
Child mortality							
1q0 [†]	Manica	53.4 (33.3 to 78.1)	21.3 (12.0 to 34.2)	-32.1 (-51.1 to -16.4)	-2.9 (-11.6 to 4.8)	0.40 (0.26 to 0.59)	1.09 (0.88 to 1.35)
1q0 [†]	Sofala	61.5 (40.6 to 89.1)	26.5 (15.8 to 41.7)	-35.0 (-55.6 to -17.7)	-	0.44 (0.28 to 0.64)	-
1q0 [†]	No Sofala	56.7 (38.6 to 78.8)	23.6 (15.3 to 34.0)	-33.0 (-52.1 to -16.9)	-1.9 (-8.1 to 3.5)	0.42 (0.28 to 0.61)	1.03 (0.88 to 1.21)
5q0 [†]	Manica	75.2 (49.3 to 108.0)	35.7 (21.4 to 54.8)	-39.5 (-66.2 to -19.2)	0.1 (-8.8 to 9.7)	0.48 (0.32 to 0.69)	1.02 (0.82 to 1.26)
5q0 [†]	Sofala	76.4 (51.5 to 107.9)	37.0 (22.5 to 57.6)	-39.4 (-66.1 to -18.9)	-	0.49 (0.32 to 0.71)	-
5q0 [†]	No Sofala	73.1 (51.8 to 100.7)	34.8 (24.0 to 49.3)	-38.3 (-62.2 to -19.0)	-1.1 (-8.7 to 5.6)	0.48 (0.33 to 0.68)	1.01 (0.86 to 1.18)

* The INCOMAS 2016 indicator was not used to compute these trends.

[†] Per 1,000 per live births.

* No Sofala indicates other provinces excluding Maputo City.

Abbreviations: 1q0, infant mortality rate; 5q0, under-5 mortality rate; ANC4+, at least four antenatal care visits; Cesar, cesarean section rate; DHS, Demographic and Health Survey; DTP3, coverage of diphtheria, tetanus, and pertussis combined vaccine; Fullimune, full immunization coverage; ID, institutional deliveries; IMASIDA, Inquérito de Indicadores de Imunização, Malária e HIV/SIDA em Moçambique; INCOMAS, Inquérito Comunitário em Manica e Sofala; IPTp2+, at least two doses of intermittent preventive treatment of malaria in pregnant women; SBA, skilled birth attendance; TxARI, acute respiratory infection treatment; TxDiar, diarrhea treatment; TxFever, fever treatment.

Discussion

Between 2010 and 2015, the Mozambique PHIT Partnership intervention implemented in Sofala province improved service coverage for three indicators of maternal and child health—at least four antenatal care visits (ANC4+), intermittent preventive treatment of malaria in pregnant women (IPTp), and skilled birth attendance (SBA)—above and beyond changes observed over same time period in Manica Province, but not compared with other provinces (i.e., the No Sofala comparator). However, the proportion of children under five with fever who received antimalarial treatment in the previous 2 weeks decreased in Sofala Province, whereas Manica province and the rest of the country saw improvements in this area. Nevertheless, the decreasing trend in child mortality in Sofala Province was similar to the rest of country. These findings should be interpreted with caution and should account for multiple countrywide efforts targeting the same service coverage and/or reductions in maternal and child mortality. If fact, in our analysis we observed improvements in maternal and child services coverage all over the country.

The Mozambique PHIT Partnership is one of the large-scale HSS interventions focusing explicitly on strengthening broad health systems in Mozambique. It simultaneously influences many of the WHO health system building blocks, in contrast to other HSS interventions, few of which have targeted the leadership/governance, information, and medical supplies building blocks³⁴. The intervention was designed to generate generalizable knowledge on how HSS approaches can improve health system functioning, translating to higher service coverage and population-level health impacts, and to address the fact that few initiatives have attempted to link HSS interventions with improved health system performance or have evaluated interventions for their impact on population-level health^{23,35}. The Mozambique PHIT service coverage and mortality evaluation was designed to rely on representative household surveys and a quasi-experimental analytic approach¹⁵, in contrast to many other impact evaluations with randomized controlled trial designs³⁴. Furthermore, the evaluation used two approaches to ensure consistency of the results: (1) a direct survey-based approach, whereby a two-step analysis was conducted by first obtaining coverages (and

variances) per survey and then computing the differences between surveys within and between provinces; and (2) a model-based approach, whereby multilevel models were aware of the geographical proximity of provinces. Both approaches showed similar point estimates of coverage and overtime changes; however, the model-based approach was substantially less uncertain.

Mozambique PHIT Partnership used data quality assurance and audit and feedback to improve the quality of routine data and develop appropriate tools to facilitate decision making for managers at the district and provincial levels. A previous evaluation of the impact of this activity showed significant improvements in the HIS data concordance across public-sector health facilities in Sofala province²⁴. This impact is essential for improving the effects of managerial support activity (another pillar of Mozambique PHIT) through, for example, providing high-quality data service provision like the supply of management of essential medicines, for better planning of future needs and prevent stock-outs. Ultimately these would lead high service coverage and mortality reductions, as suggested by a recent systematic review on RCTs using audit and feedback to improve service provision and patient outcomes³⁶.

Mozambique in general suffers from lack of health human resources for the size of the population³⁷ and particularly, in health sector there is a lack of trained or experienced managers³⁸. Mozambique PHIT Partnership was designed to address this issue at province and district level by influencing the governance and leadership system block. The competence and tasks of managers are ubiquitous in different health programs and activities, hence there are potential benefits beyond just maternal and child services provision. However, our impact assessment was not designed to capture indirect effects of the intervention.

Strengths and Limitations

We leveraged the use of 4 large community surveys conducted in Mozambique to assess changes in maternal and child health care service provision and the child mortality rate. Doing so enabled us to use a nationwide comparator for Sofala Province, rather than relying only on Manica Province as a comparator. However, one challenge with such an undertaking is an inability to guarantee that the indicator definition

did not change overtime, which could potentially affect the analysis due to data quality issues from survey to survey. For example, the 2008 Multiple Indicator Cluster Survey was conducted in Mozambique during our study period, but the procedures and data collection rigor were different from those of the DHS and IMASIDA, and therefore we could not include the 2008 survey in our analysis. Another example is that the INCOMAS 2016 experienced a problem in the electronic data collection tool (that was corrected after few weeks of data collection), which affected the collection of data related to IPTp2+. In addition, areas of Sofala and Manica provinces suffered military attacks in 2016, as well as flooding in the central region a few weeks after data collection began. These two events affected the logistics and the administration of the survey.

For this analysis, we used survey design and model-based procedures in such a way that one served as a sensitivity analysis for the other. The model-based approach simultaneously accounts for the geographically proximity of the province level and temporal changes of the indicator. However, we were able to use only province geographical proximity because the DHS surveys did not include geographical information at the lower levels. Future large community surveys in Mozambique should include geographical information after an anonymization procedure is guaranteed. Nevertheless, our impact model-based point estimates were similar in direction and strength to survey-based estimates; however, the model-based findings were more precise. Also, in the model-based approach we leveraged the fact that although each community survey is cross-sectional, each pregnancy and childbirth are indexed to a calendar date. We used linear terms for time parametrization before and after the intervention based on this calendar information.

Although community surveys are intended to be representative at the national and provincial levels, they are still prone to social desirability bias and recall bias, given that each survey asks questions about pregnancy, delivery, and children or babies born in the previous five years. Finally, we chose a limited number of indicators along the maternal and child health care continuum, based on data availability and the nature of the intervention to influence the indicator. We believe that the earlier stages of the health care continuum were more susceptible to intervention.

Conclusion

This study provides evidence that the PHIT Partnership intervention had a positive impact on selected maternal and child health service indicators (number of antenatal care visits, at least two doses of intermittent preventive treatment of malaria, and skilled birth attendance) in Sofala province between 2010 and 2015; however, it did not affect child mortality rates and it was associated with reduction in number of children treated for fever. These findings have important implications both within Mozambique and for the larger global health community. HSS interventions should incorporate the governance/leadership and health information health system building blocks to strengthen coordination and provide timely feedback while managing the intervention. In addition, HSS assessments should first consider the availability of data and try to leverage data sources before deciding to proceed with additional data collection.

Abbreviations

1q0	infant mortality rate
5q0	under-five mortality rate
AD	absolute differences
ANC4+	at least four antenatal care visits
DHS	Demographic and Health Survey
DPD	difference in proportion differences
DTP	diphtheria, tetanus and pertussis vaccine
Cesar	cesarean section rate
Fullimune	full immunization coverage
GDP	gross domestic product
ID	institutional delivery
IMASIDA	Inquérito de Indicadores de Imunização, Malária e HIV/SIDA em Moçambique

INCOMAS	Inquérito Comunitário em Manica e Sofala
IPTp2+	at least two doses of intermittent preventive treatment of malaria
PHIT	Population Health and Implementation Training
PR	proportion ratios
RPR	ratio of proportion ratios
SBA	skilled birth attendance
TB	tuberculosis
TxARI	acute respiratory infection treatment
TxDiar	diarrhea treatment
TxFever	fever treatment
WHO	World Health Organization
WRA	women of reproductive age

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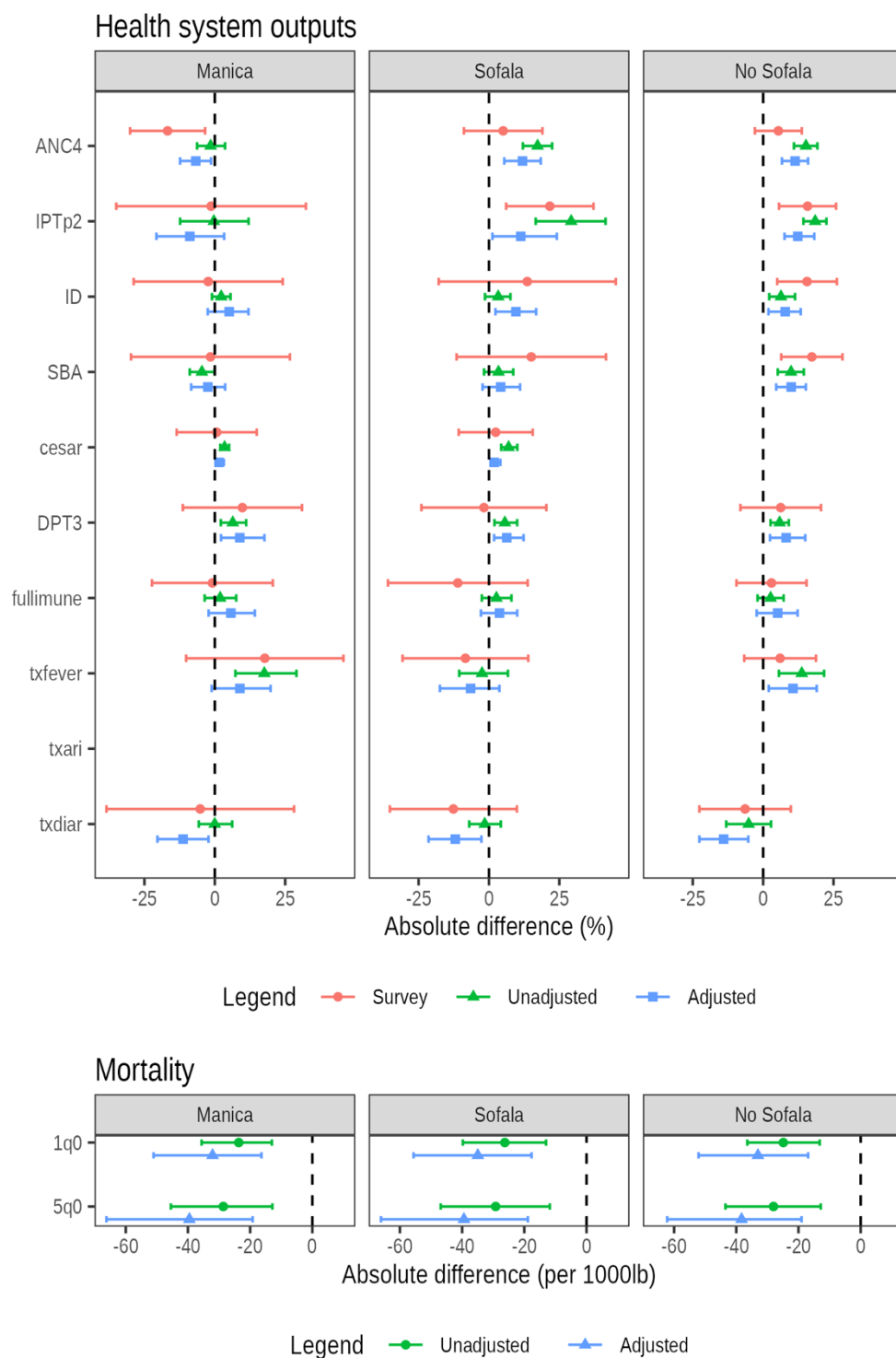


Figure 2.1 - Absolute differences of the output and outcome indicators from 2010 to 2015.

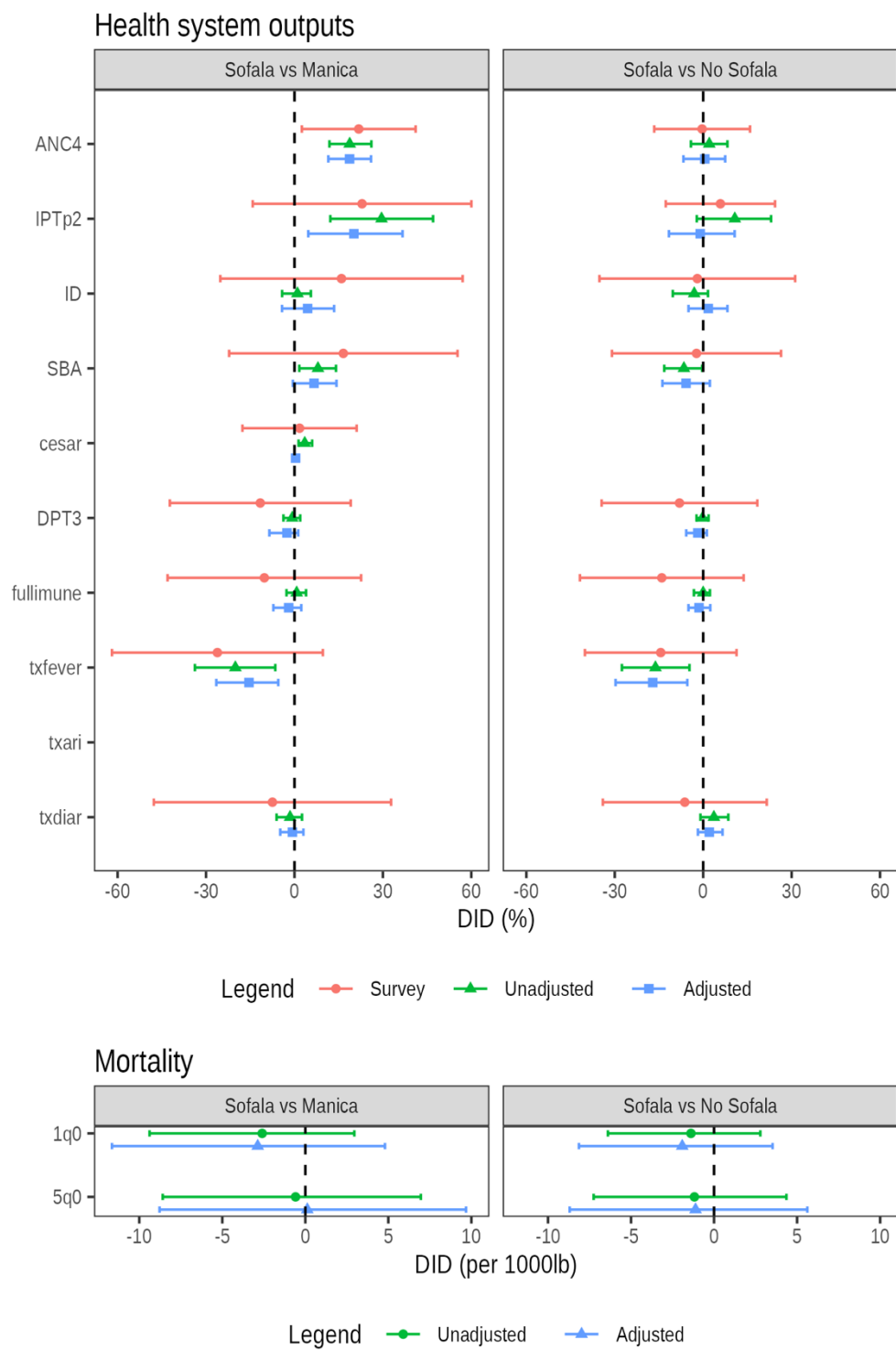


Figure 2.2 - Difference in proportion differences between 2010 to 2015 of the output and outcome indicators.

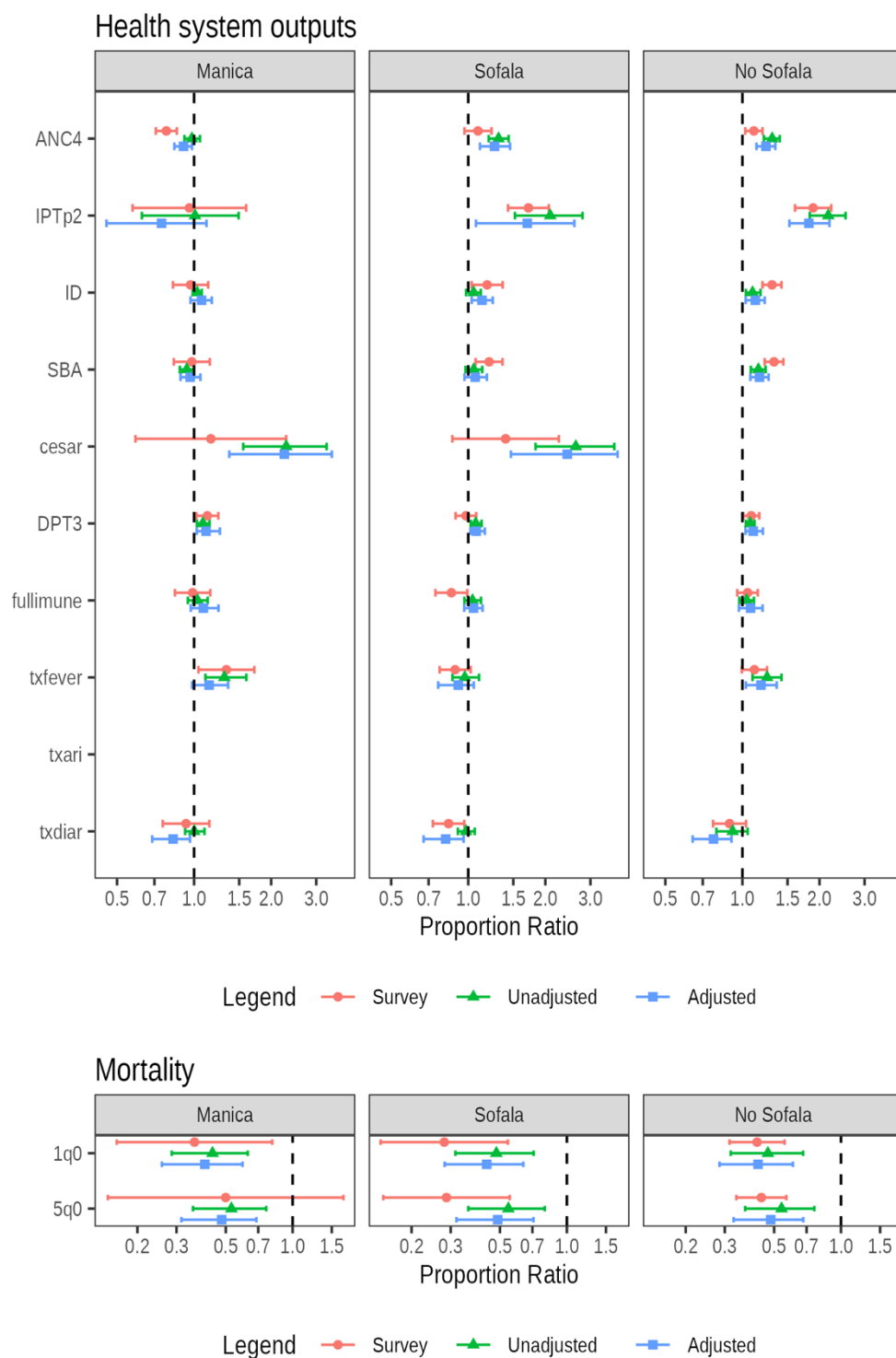


Figure 2.3 - Proportion ratios of the output and outcome indicators from 2010 to 2015

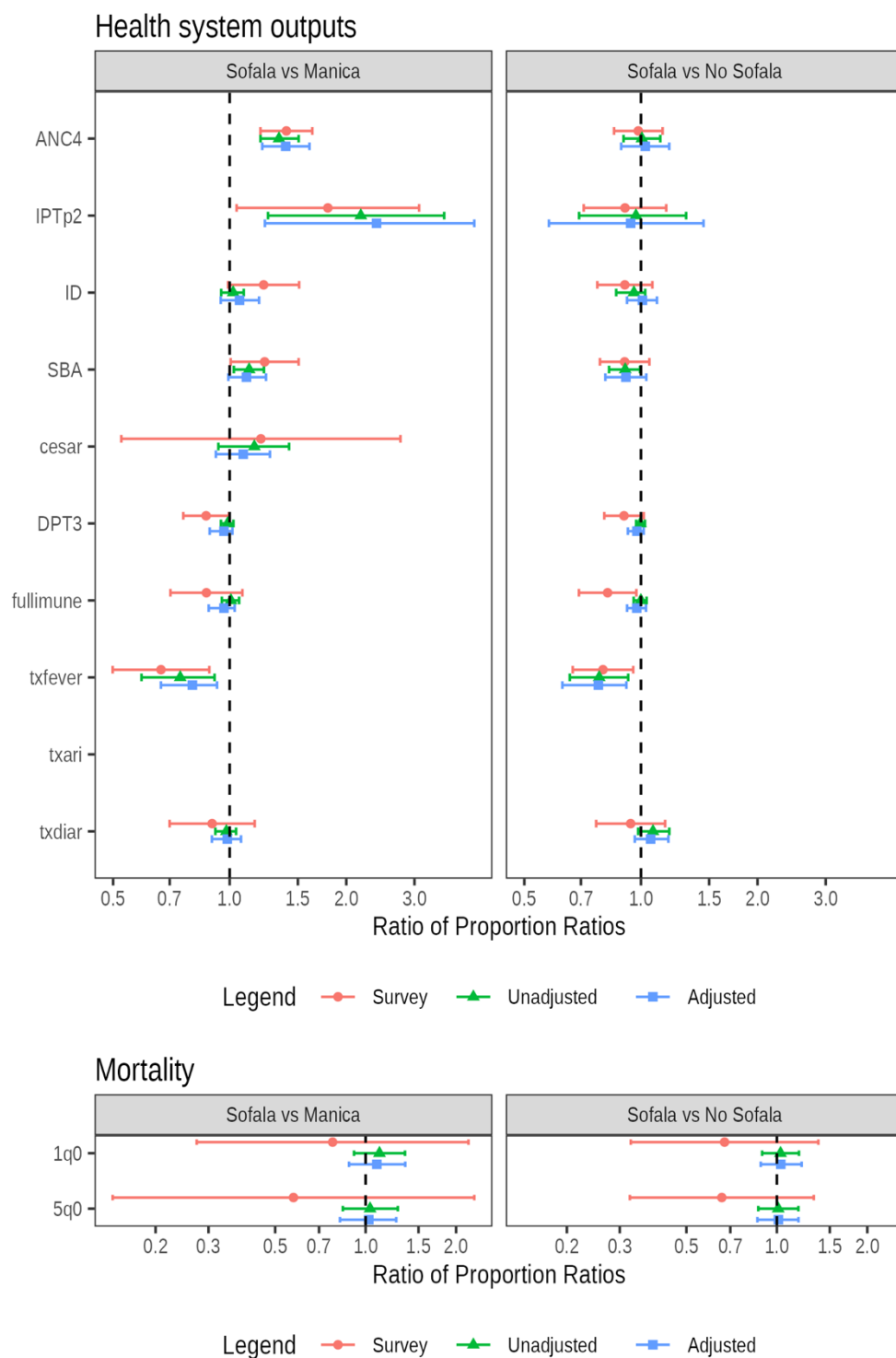


Figure 2.4 - Ratio of proportion ratios between 2010 to 2015 of the output and outcome indicators

Chapter 3: Health Services Provision Effect of the Mozambique African Health Initiative

CHAPTER 3: HEALTH SERVICES PROVISION EFFECT OF THE MOZAMBIQUE AFRICAN HEALTH INITIATIVE

Abstract

Background: The Population Health Implementation and Training (PHIT) Partnership in Mozambique was a large health system strengthening project affecting multiple World Health Organization health system building blocks, particularly the leadership/governance and information blocks. We assessed maternal and child health care service provision outcomes using data from Módulo Básico, the national routine health information system.

Methods: We conducted uncontrolled and controlled interrupted time series analysis to assess improvements in maternal and child health care service provision within Sofala Province (intervention site) and between Sofala Province and Manica Province (control site). The intervention was between 2010 and 2015, so interruptions were set at January 2010 and January 2012. Data between January 2008 and November 2015 were included. Six indicators were chosen based on an evaluation framework common to all partnership sites and data availability: first antenatal care visits; HIV testing during antenatal care services; intermittent preventive treatment for malaria among pregnant women; institutional deliveries; diphtheria, pertussis, and tetanus toxoid vaccination coverage among children; and measles vaccination coverage among children. Outcomes are represented by monthly counts of services provided at each health facility. We fit negative binomial regression models to capture within-province changes as relative ratios and between-province changes as ratios of relative ratios to account for facility catchment area sizes.

The assessment included 185 health centers that provided at least 12 months of data before and after 2010.

Results: the PHIT Partnership in Mozambique was associated with improvement of 30% (RRR, 1.30; 95% CrI, 1.22 to 1.38) and 21% (RRR, 1.21; 95% CrI, 1.13 to 1.30) above and beyond than the control in first antenatal care visits 1000 per WRA and institutional delivery per 1000 WRA, respectively. But, although there were improvements within the intervention arm, there was a net relative reduction for maternal HIV testing (RRR, 0.88; 95% CrI, 0.83 to 0.93) and malaria prophylactic treatment (RRR, 0.60; 95% CrI, 0.53 to 0.69) or long-term immunization services among children [measles (RRR, 0.85; 95% CrI, 0.77 to 0.93) and DTP3 (RRR, 0.89; 95% CrI, 0.80 to 0.99)].

Conclusions: The Mozambique PHIT Partnership improved service provision for first antenatal care visits and institutional deliveries. Routine health information systems are important data sources and can be leveraged for large health systems strengthening projects.

Background

Globally, there has been an improved understanding of the role of national health systems to deliver proven, efficacious interventions. Health systems are considered the main instrument for closing the gap between knowledge and action in health interventions¹⁻³. And indeed, multiple efforts of health systems strengthening (HSS) have increased since 2005 to improve the service provision and health outcomes⁴. However, there has been underinvestment in health system research and non-robust evaluation designs to assess system-wide effects⁴⁻⁶.

In 2007 the Doris Duke Charitable Foundation launched the African Health Initiative “to help catalyze a shift from current public health focus on single-disease programs to an emphasis

on strengthening health systems to effectively deliver integrated primary care to underserved populations.”⁷ The African Health Initiative was created as a research-based initiative to help understand how health systems strengthening (HSS) can improve population health, shedding light on how to make interventions with a solid evidence base available, accessed, and used by served populations. Through the African Health Initiative, HSS interventions were implemented in five countries—Ghana, Mozambique, Rwanda, Tanzania, and Zambia. Each country created its own Population Health Implementation and Training (PHIT) Partnership based on a common evaluation framework that included core indicators, although each program was distinct in its intervention and evaluation designs^{7,8}. The partnerships in each country emphasized integrated interventions that encompassed multiple components of the World Health Organization (WHO) framework of six health system building blocks, rather than focusing on historically targeted HSS regional interventions such as performance-based financing or community health worker programs^{9–14}. Here we focus on reporting the results of the PHIT Partnership in Mozambique.

The Mozambique PHIT Partnership was established through a seven-year grant, with the overall goal to improve health outcomes in all 13 districts of Sofala Province by strengthening health systems and improving the delivery of integrated primary health care services. The three major aims were to (1) strengthen integrated health systems management in Sofala at the district and provincial levels; (2) improve the quality of routine data and develop appropriate tools to facilitate decision making for provincial and district managers; and (3) strengthen capacity for and conduct innovative operations research, including program evaluation, to guide integration and systems strengthening efforts.

The impact evaluation of the Mozambique PHIT Partnership included community-level changes in the coverage and utilization of key maternal and child health care services and child

mortality, as well as health system service delivery outputs. Here, we assess improvements at the health facility level for selected indicators, reported as monthly counts of service provision based on data from the routine health information system.

Methods

Study Design and Study Settings

We conducted uncontrolled and controlled interrupted time series analysis of monthly counts of delivered services between January 2008 and November 2015 at health facilities within Sofala Province (the intervention site) and Manica Province (the control site). We set the time interruption in January 2010. Because of the nature of the intervention to improve primary health care provision, only health centers were included in the analysis. We chose to include only health centers because of 1) the nature of the intervention (targeting maternal child services (MCH) provision), which is primary health care; 2) lower-level health facilities (different health posts), although they might be classified as public, they tend to belong to a private company, especially in industrious areas of Sofala, and do not perform deliveries; 3) higher level health facilities (such as district, provincial and central hospitals) are fewer and offer broad more services well beyond MCH.

Sofala Province was chosen as the geographic and administrative area to implement the PHIT Partnership model based on a successful 20-year collaboration between the Ministry of Health (MOH), Sofala Provincial Health Directorate (Direcção Provincial de Saúde de Sofala), Eduardo Mondlane University School of Medicine, Health Alliance International, and the University of Washington Department of Global Health ¹⁰.

Sofala Province is located in the central region of Mozambique and is considered one of the poorest of the country's 11 provinces. By 2009, the population of Sofala was 1.8 million, of which 63% lived in rural areas, although 62% of the population of province lived on the Beira corridor (the transportation route that links the seaport of Beira to Zimbabwe). Sofala Province had higher rates of child mortality (infant mortality rate of 81 per 1,000 live births and under-five mortality rate of 134 per 1,000 live births), a higher burden of HIV (15.5% of adults ages 15-49, and about 60,000 people needing antiretroviral treatment, of whom 23,800 were at pediatric age), and high levels of child malnutrition (prevalence of chronic malnutrition among children under five is 35.7%) compared with other provinces in the country^{15,16}. Manica Province is located directly west of Sofala Province and is also served by the Beira corridor. By 2009, Manica Province had 1.6 million inhabitants, with 63.8% residing in rural areas. It has a high child and infant mortality rate (154 and 64.4 deaths per 1,000 live births), high levels of child malnutrition (prevalence of chronic malnutrition among children under five is 21%), and high HIV burden (adult HIV prevalence of 15.3%). The capital cities of Chimoio (in Manica) and Beira (in Sofala) alone represented 16.7% and 25.4% of each province's total populations¹⁷⁻¹⁹. Both provinces were severely affected by the 16 years of civil war that ended in 1992 with a peace agreement. However, military instability returned in 2014, with many districts along the Beira corridor affected²⁰.

Data Sources

For monthly counts of service provision at the health facility level, we used data from Módulo Básico, the health information system used by the MOH between 2003 and 2015 to collect, transfer, and manage routine health information for the purpose of program monitoring and evaluation. The most disaggregated data is from the health facility level, entered through paper forms at the district level, and then transmitted to provincial and national levels through USB flash

disks or email. We obtained two national-level datasets from Módulo Básico: one covered the period from mid-2005 to December 2011, and another covered the period from March 2012 to mid-2015. Therefore, we have missing data for January and February 2012. In addition, within each period, there are time points with missing data or with less than 10% of health facilities reporting data for any indicator—particularly for service provision counts of intermittent preventive treatment (IPTp) for malaria among pregnant women prior to 2012 because it was not consistently collected.

We used datasets from the Service Availability and Readiness Assessment (SARA) 2017 survey and SISMA (Sistema de Informação de Saúde para Monitoria e Avaliação), the successor to Módulo Básico, to confirm health facility names and obtain catchment areas for each health facility.

Data Processing

We combined the two datasets from Módulo Básico to obtain 2,917,779 observations corresponding to 2,246 health facilities. We then restricted the datasets to include data only from Manica and Sofala provinces and only after January 2008. The dataset prior to 2008 had substantially fewer health facilities reporting across the indicators selected for this analysis. We also eliminated duplicates and removed aggregated reports from districts and provinces, outreach data, military and police health facilities, prisons and companies, and other private unities. This resulted in a remainder of 23,094 observations corresponding to 318 health facilities (Table 3.1). Of these, 65 health facilities could not be found in either of the SARA or SISMA datasets.

Table 3.1. Number of health facilities processed.

Province	Health Facility Type*	Módulo Básico Raw Data		Módulo Básico Data With Minimal Completeness		Módulo Básico Data With Catchment Sizes	
		# Health	#	# Health	# Observations	# Health	# Observations
		Facilities	Observations	Facilities		Facilities	
Manica	Health Centers	98	7883	79	7123	78	7031
	Provincial Hospital	1	92	1	92	0	0
	Other Hospitals	3	275	3	275	2	183
	Health Posts	0	0	0	0	0	0
	Undetermined	0	0	0	0	0	0
Total	-	102	8250	83	7490	80	7214
Sofala	Health Centers	128	10586	109	9795	107	9662
	Central Hospital	1	93	1	93	0	0
	Other Hospitals	5	465	5	465	5	465
	Health Posts	17	1316	17	1316	13	1039
	Undetermined	65	2384	32	1768	0	0
Total	-	216	14844	164	13437	125	11166
Overall	Health Centers	226	18469	188	16918	185	16693
	Central/Provincial Hospital	2	185	2	185	0	0
	Other Hospitals	8	740	8	740	7	648
	Health Posts	17	1316	17	1316	13	1039
	Undetermined	65	2384	32	1768	0	0
Total	-	318	23094	247	20927	205	18380

* Type of facility is according to SISMA data. The “undetermined” category is for health posts according to data from Módulo Básico.

We applied a restriction based on the number of observations between January 2008 and January 2010 and between January 2010 and November 2015. Within each period, we included only those health facilities that reported data for at least 12 months. There were 20,927 observations corresponding to 247 health facilities. Of these health facilities, 215 were matched in the SARA and SISMA datasets, of which 188 were health centers. We further restricted the data to include only the 188 health centers, the main target of the intervention; however, an additional 3 health facilities were excluded because no catchment area estimates were provided in the data sources consulted. This resulted in a total of 185 health centers included in the analysis.

Overall, in the 96 months (from January 2008 to December 2015) of the evaluation there should be 7,488 and 10,272 observations, respectively, in Manica and Sofala. There were, respectively, 476 (6.4%) and 839 (8.2%) months with the 6 indicators missing simultaneously; and there were 5,169 (69.0%) and 6,238 (60.7%) months with at least one indicator missing, respectively with the IPTp2+ being the main contributor for the missing. So, assessing the proportions of months with at least one indicator missing after removing IPTp2+ Manica and Sofala had 24.7% and 30.1%, respectively. Overtime (figures S1 and S2), the patterns in both provinces were similar. However, there was province differential patterns before 2010, with Manica with less missing compared to Sofala. In order to proceed to the analysis, we consider these patterns of missing data as missing at random (MAR)²¹.

Variables

We selected monthly counts of service provision at the health facility level for the following six maternal and child health care service provision indicators available in Módulo Básico: (1) first antenatal care visits (FirstANC); (2) newly HIV tested women in antenatal care

(newlyHIV); (3) pregnant women who have received at least two doses of intermittent preventive treatment of malaria (IPTp2+); (4) institutional deliveries (DEL); (5) children under the age of 1 year who have received the third dose of the combined diphtheria, tetanus toxoid, and pertussis (DTP3) vaccine; and (6) children under the age of 1 year taking the measles vaccine (MEASLES). Monthly counts of IPTp service provision were not consistently collected in Módulo Básico prior to January 2012; however, we included this indicator because it aims to prevent one of the highest burdens of mortality and comorbidity in central Mozambique.

We obtained catchment area sizes (i.e., total populations near the health facility) as estimates for 2015 in SISMA. We applied a 3% yearly decrease going backward in time to estimate the catchment sizes during our study period. The MOH uses the factors 0.249 and 0.171, respectively, to obtain the total number of women of reproductive age (WRA) and the total population under the age of 5 years. These factors were established together with the National Institute of Statistics (INE) and represent an average proportion of these groups in the overall population.

Statistical Analysis

Descriptive statistics, including means (standard deviation [SD]), median (interquartile range [IQR]), range for numeric variables, and frequencies (proportions) are used. For each indicator, we conducted uncontrolled and controlled interrupted time series analysis using a mixed-effects negative binomial regression. The health facility and the district were included as random intercepts. The time is included in months and is split into three segments (linear splines). Segment 1 is from January 2008 to December 2009 (pre-2010), segment 2 is between January 2010 and December 2011 (induction period), and segment 3 is from January 2012 onward until November

2015 (post-2012). We placed a jump (an immediate change) in January 2010 and a knot in January 2012. The following equation expresses the parametrization of the model:

$$\begin{aligned} \log(E(count_{ht})) = & (\beta_0 + u_h + u_d) + \\ & \beta_1 \cdot timepre_t + \beta_2 \cdot post2010_t + \beta_3 \cdot timepost2010_t + \beta_4 \cdot timepost2012_t \\ & \beta_5 \cdot province_h + \beta_6 \cdot timepre_t \cdot province_h + \beta_7 \cdot post2010_t \cdot province_h + \\ & \beta_8 \cdot timepost2010_t \cdot province_h + \beta_9 \cdot timepost2012_t \cdot province_h \\ & + \sum_{m=1}^{11} [\gamma_m \cdot I(month(time) = m)] + 1 \cdot \log(population_{ht}) \end{aligned}$$

Where count is the outcome of interest at time t , at health facility h ; timepre is the count of time in months from January 2008 to June 2015 (centered in January 2010); post2010 is a dummy indicator (0 indicates before January 2010, 1 indicates since January 2010); timepost2010 counts time in months since January 2010; and timepost2012 counts time in months since January 2012. The logarithm of the population is included as an offset; therefore, the above equation models the ratio between the count and population. For counts of first antenatal care visits (FirstANC) and institutional deliveries (DEL), we used the WRA estimates for the population. For at least two doses of intermittent preventive treatment for malaria in pregnancy (IPTp2+) and newly HIV tested women in antenatal care (newlyHIV), we used the FirstANC visits. For child health service delivery indicators (DTP3 and MEASLES doses), we used the estimates of live births for the month. The terms in the summation are 11-month dummy indicators to account for seasonality. We used sum contrasts dummy coding, so each gamma coefficient is a deviation from the center of the year.

The exponentiated intercept, e^{β_0} , represents the ratio count and catchment size by the end of 2009 in Manica Province, whereas for Sofala Province, it is $e^{\beta_0 + \beta_5}$. The exponentiated jump, e^{β_2} , represents the immediate multiplicative change in the overall ratio (count to population) from

the end of pre-2010 (time segment 1) to the beginning of the induction period (time segment 2) in Manica Province, whereas for Sofala, it corresponds to $e^{\beta_2 + \beta_7}$. The monthly multiplicative change pre-2010 in Manica and Sofala, respectively, are captured by e^{β_1} and $e^{\beta_1 + \beta_6}$. During the induction period in Manica and Sofala, respectively, the multiplicative changes in the pre-2010 trends are captured by e^{β_3} and $e^{\beta_3 + \beta_8}$. The relative change of the trend in post-2012 (time segment 3) compared with pre-2010 in Manica and Sofala, respectively, are captured by $e^{\beta_3 + \beta_4}$ and $e^{\beta_3 + \beta_4 + \beta_8 + \beta_9}$. The ratio of the quantity in Sofala and the same quantity in Manica (relative ratios, RR) are of interest because they show the relative gains in Sofala compared with Manica.

We applied the same parametrization for all outcome indicators except IPTp2+. For IPTp2+, we removed all terms capturing the segments prior to January 2012. All regression models were estimated through the Bayesian framework using Stan programming language in the brms library ²² in R version 4.3.1. The software default priors (uninformative and diffuse priors) were found to be appropriate for this analysis after the number of iterations was increased to 20,000 (5,000 per chain), and a thinning interval of 5 and 1,000 observations in the burn-up period. We assessed the MCMC (Markov Chain Monte Carlo) convergence using the R-hat statistic and visual inspection of the trace plots of the MCMC chains. We report the point estimates and 95% credible intervals (CrI). We summarized the random effects of the models by reporting their standard deviations and reporting the variance partition as estimated as $1 - var_no_re/var_total$, where var_no_re is the estimated variance of the posterior predictive distribution with random-effects set to 0, and var_total the estimated variance of the posterior predictive distribution reported by brms with the random effects.

Ethical Considerations

This is a secondary data analysis from Módulo Básico, the national health information system, and no patient information is included. However, the National Directorate of Public Health approved the use of the data.

Results

General and Pre-Intervention Characteristics

By 2009, Manica and Sofala provinces had about 1.5 and 1.8 million inhabitants, respectively, with health facilities covering 80.5% and 75.9% of the population (Table 3.2). There are 10 districts in Manica and 13 in Sofala, with an average of 143,633 inhabitants per district in Manica and 110,002 per district in Sofala, after excluding the capital cities of the provinces. Although the capital city of Sofala Province had 73% more people than the capital city of Manica Province (449,238 versus 258,683), after excluding the capital cities, the populations of the two provinces looked similar in terms of their proportions of WRA (23.4% versus 23.0%) and children under the age of 1 year (3.8% versus 4.3%).

The health facilities included in the analysis covered an estimated 78.0% of the population in Manica and Sofala. A typical health facility, excluding those in the capital cities, covers 14,005 people, with no substantial average difference between provinces. However, there was substantial variation between the catchment sizes of health facilities (IQR 6,037 to 21,552 in Manica; IQR 5,961 to 14,533 in Sofala). The ratios of service delivery (Table 3.2) were similar for both provinces in the period prior to implementation of the intervention.

Table 3.2. Demographic characteristics of Sofala and Manica provinces and health facilities included in the analysis.

Characteristic	Manica Province		Sofala Province	
	N	%	N	%
Total population in 2009*	1,551,378		1,769,263	

Total WRA in 2009	356,467	23.0	413,231	23.4
Total under-5 in 2009	297,655	19.2	313,089	17.7
Total under-1 in 2009	66,301	4.3	67,679	3.8
Total population in the capital of a district	258,683	16.7	449,238	25.4
Number of districts	10		13	
Average population per district [†]	143,633		110,002	
Median, IQR of population per district [†]	139,700 (75,152 to 216,436)		118,069 (65,305 to 136,921)	
Number of HF included in the analysis	78		107	
Total catchment of HF	1,248,306	80.5	1,342,563	75.9
Mean catchment of HF	16,004		12,547	
Median (IQR) catchment	11,366 (6,037 to 21,552)		9,105 (5961 to 14,533)	
Pre-2010 average and CV				
First ANC visit	75	112.2	52	111.1
Ratio per 1,000 WRA	20.3		17.7	
IPTp2+**	-	-	-	-
Ratio per 100 first ANC visits	-	-	-	-
Newly HIV tested in ANC	76	116.4	58	107.0
Ratio per 100 first ANC visits	101.7		112.3	
Institutional deliveries	31	121.3	29	159.9
Ratio per 1,000 WRA	8.4		9.8	
Ratio per 100 first ANC visits	41.2		55.0	
DTP3 doses in under 12 months	51	129.8	36	113.4
Ratio per 100 under-1	73.8		74.8	
Measles doses in under 12 months	46	138.7	31	124.9
Ratio per 100 under-1	67.5		65.4	

* From Census 2007 population projections

[†] Excluding the capital of the province

** No data from IPTp2+ prior to 2010

Abbreviations: ANC, antenatal care; DTP3, third dose of diphtheria, tetanus toxoid, and pertussis combined vaccine; HF, health facility; IPTp2+, number of pregnant women who have received at least two doses of intermittent

preventive treatment for malaria; IQR, interquartile range; CV, coefficient of variation; WRA, women of reproductive age.

Maternal Health Service Delivery Outcomes

Table 3.3 and Figures 3.1 and 3.2 show the within-province annual relative changes and additional multiplicative changes in Sofala compared with Manica. Health centers in Manica and Sofala, respectively, had 18.8 and 15.5 first antenatal care (ANC) visits per 1,000 WRA by the end of 2009, with annual increases of 5% (RR, 1.05; 95% CrI, 1.01 to 1.09) and 0.0% (RR, 1.00; 95% CrI, 0.96 to 1.03) prior to 2010. Overall, from January 2010 to November 2015, Manica health centers showed a decline in first ANC visits, from 19.4 to 18.4 visits per 1,000 WRA, a 5% decrease (RR, 0.95; 95% CrI, 0.91 to 0.99), whereas Sofala health centers showed a 23% increase in first ANC visits (RR, 1.23; 95% CrI, 1.18 to 1.28), from 17.0 to 21.0 visits per 1,000 WRA (Figure 3.3 and Table S7). Therefore, Sofala showed a statistically significant net gain of 30% in first ANC visits (RRR, 1.30; 95% CrI, 1.22 to 1.38) beyond Manica (Figure 3.2 and Table S7).

At the end of 2009, the ratio of newly HIV tested women in ANC per 100 women presenting to their first ANC visits at health centers in Manica and Sofala, respectively, was 90.8 and 94.9. By December 2015, these ratios changed to 96.4 and 98.0, respectively, showing a statistically significant reduction of 12.3% (RRR, 0.877; 95% CrI, 0.829 to 0.929) in Sofala relative to Manica (Figure 3.2 and Table S7), despite a statistically significant relative gain of 11% (RRR, 1.11; 95% CrI, 1.02 to 1.20) at the beginning of the intervention period.

Between January 2012 and November 2015, the ratio of pregnant women completing at least two doses of IPTp2 per 100 women presenting to their first ANC visit changed from 47.8 to 59.8 in Sofala, whereas in Manica during the same period, the ratio changed from 25.5 to 53.0. Therefore, Sofala showed an increase of 25% (RR, 1.25; 95% CrI, 1.15 to 1.35) compared with an

increase of 2.08 times (RR, 2.08; 95% CrI, 1.87 to 2.31) in Manica i.e. Sofala since January decreased 40% (RRR, 0.60; 95% CrI, 0.52 to 0.69) beyond the Manica trend (Tables 3.3 and S7).

The estimated number of institutional deliveries per 1,000 WRA in Manica health centers changed from 8.0 to 10.3, an increase of 1.19 times (RR, 1.19; 95% CrI, 1.13 to 1.26) between January 2010 and December 2015, whereas in Sofala it changed from 8.2 to 11.9 during the same period, corresponding to an increase of 1.44 times (RR, 1.44; 95% CrI, 1.38 to 1.51) (Tables 3.3 and S7). Therefore, the number of institutional deliveries in Sofala showed a statistically significant increase of 21% (RRR, 1.21; 95% CrI, 1.13 to 1.30) beyond what was seen in Manica. Most of the gains in Sofala were associated with the period from 2010 to 2012 (Table 3.3).

Table 3.4 shows the magnitude captured by the random effects. Apart from the newly HIV-tested women in ANC per 100 women, all maternal health service delivery outcomes have substantial heterogeneity as the variance ratios are above 20%.

Child Health Service Delivery Outcomes

By January 2010, Sofala had a 23% (RR, 0.77; 95% CrI, 0.57 to 1.04) lower ratio of administered third doses of DTP3 among children under the age of 1 year per expected live births than Manica (Tables 3.3 and S7). In Sofala, the ratio changed from 64.1 to 77.3 (95% CrI, 1.63 to 1.86), a statistically significant increase of 1.74 times, whereas in Manica the ratio changed from 83.3 to 91.1 (95% CrI, 1.81 to 2.10), a statistically significant increase of 1.95 times. Therefore, Sofala did not see similar improvements as seen in Manica, with a statistically significant relative difference of 11% (RRR, 0.89; 95% CrI, 0.81 to 0.99) (Tables 3 and S7, and Figures 3.1, 3.2 and 3.3).

For measles vaccination doses administered at the age of 9 months, Sofala had a 35% lower ratio (RR, 0.65; 95% CrI, 0.47 to 0.91) of the number of doses per expected live births than

Manica (Tables 3.3 and S7) by January 2010. Between January 2010 and December 2015, the ratio in Sofala did not change (RR, 1.00; 95% CrI, 0.93 to 1.10) from 71.3, whereas Manica showed an increase of 18% (RR, 1.18; 95% CrI, 1.10 to 1.27) from 80.1. Overall, Sofala was outperformed by Manica with a significant fewer measles vaccinations relative to Manica, with a difference of 15% (RRR, 0.85; 95% CrI, 0.77 to 0.93) (Tables 3.3 and S7, and Figures 3.1, 3.2, and 3.3).

Table 3.3. Annual relative changes in outcomes by time segment in Manica and Sofala provinces and multiplicative changes (RRR, ratio of relative ratios) in Sofala relative to Manica

Indicator	Parameter*	Relative Change Within Province (RR) (95%CrI)		RRR [†] (95%CrI)
		Manica Province	Sofala Province	
First ANC (per 1,000 WRA)	intercept	18.82 (15.00; 23.55)	15.48 (12.61; 19.02)	0.82 (0.64; 1.07)
	pre-2010 slope	1.05 (1.01; 1.09)	1.00 (0.96; 1.03)	0.95 (0.91; 1.00)
	Jump	1.03 (0.97; 1.09)	1.10 (1.04; 1.16)	1.07 (0.99; 1.16)
	2010 to 2012 slope	0.95 (0.92; 0.97)	0.99 (0.97; 1.02)	1.05 (1.01; 1.09)
	post-2012 slope	1.01 (1.00; 1.03)	1.06 (1.05; 1.07)	1.04 (1.03; 1.06)
Newly HIV tested in ANC (per 100 first ANC)	intercept	90.82 (86.38; 95.55)	94.93 (90.41; 99.71)	1.05 (0.98; 1.12)
	pre-2010 slope	0.98 (0.94; 1.02)	0.98 (0.94; 1.03)	1.01 (0.95; 1.07)
	Jump	0.91 (0.86; 0.96)	1.01 (0.95; 1.07)	1.11 (1.02; 1.20)
	2010 to 2012 slope	1.04 (1.01; 1.07)	0.98 (0.96; 1.01)	0.95 (0.91; 0.98)
	post-2012 slope	1.02 (1.01; 1.03)	1.02 (1.01; 1.03)	0.99 (0.98; 1.01)
IPTp2+ (per 100 first ANC)	intercept	25.49 (22.59; 29.30)	47.83 (43.32; 53.94)	1.88 (1.59; 2.22)
	post-2012 slope	1.21 (1.20; 1.24)	1.06 (1.06; 1.08)	0.88 (0.85; 0.91)
Deliveries (per 1,000 WRA)	intercept	8.00 (6.02; 10.72)	7.22 (5.54; 9.46)	0.90 (0.68; 1.19)
	pre-2010 slope	1.04 (0.99; 1.09)	1.02 (0.98; 1.07)	0.99 (0.93; 1.05)
	Jump	1.08 (1.01; 1.16)	1.14 (1.07; 1.22)	1.06 (0.96; 1.16)
	2010 to 2012 slope	0.95 (0.92; 0.99)	1.03 (1.00; 1.06)	1.08 (1.03; 1.12)
	post-2012 slope	1.07 (1.06; 1.09)	1.08 (1.07; 1.10)	1.01 (0.99; 1.03)
DTP3 doses per 100 expected monthly live births	intercept	83.32 (63.80; 108.06)	64.11 (50.58; 80.91)	0.77 (0.57; 1.04)
	pre-2010 slope	0.92 (0.86; 0.99)	0.89 (0.83; 0.94)	0.96 (0.87; 1.05)
	Jump	0.56 (0.51; 0.62)	0.69 (0.63; 0.76)	1.23 (1.08; 1.41)
	2010 to 2012 slope	1.21 (1.16; 1.26)	1.26 (1.21; 1.31)	1.05 (0.99; 1.11)
	post-2012 slope	1.08 (1.06; 1.10)	1.02 (1.01; 1.04)	0.95 (0.92; 0.97)
	intercept	80.10 (60.84; 105.73)	52.11 (40.92; 66.58)	0.65 (0.47; 0.91)

Measles doses per 100 expected	pre-2010 slope	0.98 (0.91; 1.05)	0.85 (0.80; 0.90)	0.86 (0.79; 0.94)
monthly live births	Jump	0.92 (0.83; 1.02)	1.37 (1.25; 1.50)	1.48 (1.30; 1.69)
	2010 to 2012 slope	0.90 (0.86; 0.94)	0.89 (0.86; 0.93)	0.99 (0.94; 1.05)
	post-2012 slope	1.10 (1.08; 1.12)	1.06 (1.04; 1.08)	0.96 (0.94; 0.99)

* The parameters are estimated for each outcome through a negative binomial regression. The intercept is the level of the indicator at beginning of 2010, whereas the slope parameter captures the relative yearly change, and the jump is relative change from end of pre-2010 period to 2010 to 2010 period.

† The ratio of relative ratios (RRR) is the ratio of relative change within Sofala Province to the relative change within Manica Province. Values above 1 indicate that relative change in Sofala (intervention) were beyond the observed change in Manica (control).

Abbreviations: ANC, antenatal care; DTP3, third dose of diphtheria, tetanus toxoid, and pertussis combined vaccine; IPTp2+, at least two doses of intermittent preventive treatment of malaria in pregnancy; RR, relative ratio; RRR, ratio of relative ratios.

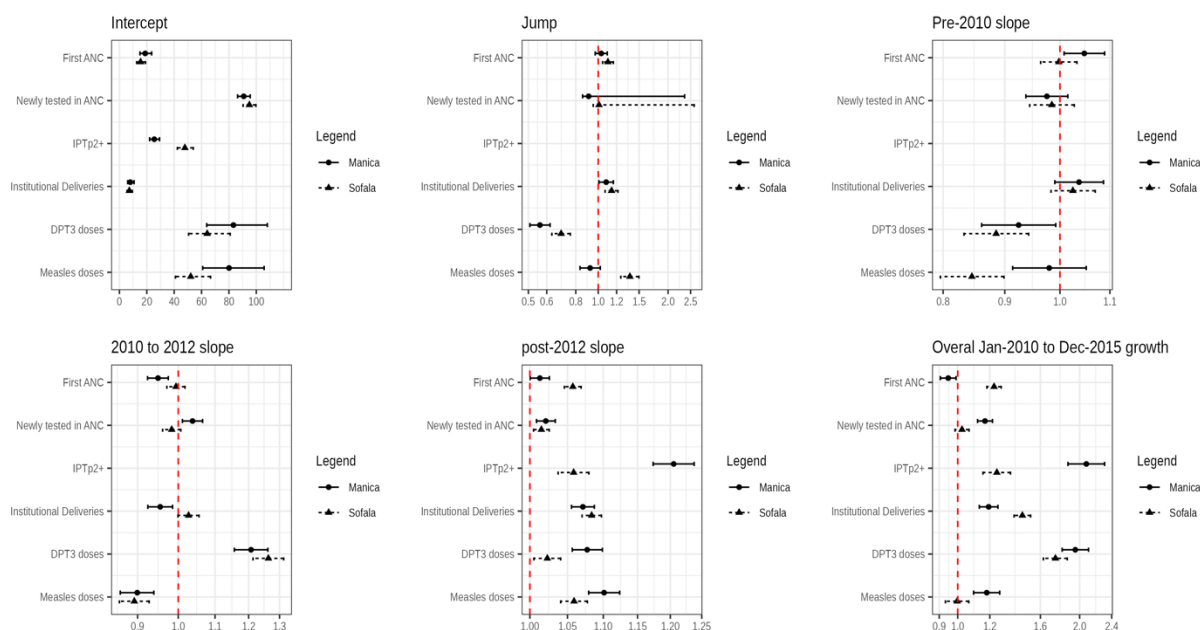


Figure 3.1. Yearly relative level changes of the outcomes in each segment of time for Manica and Sofala provinces

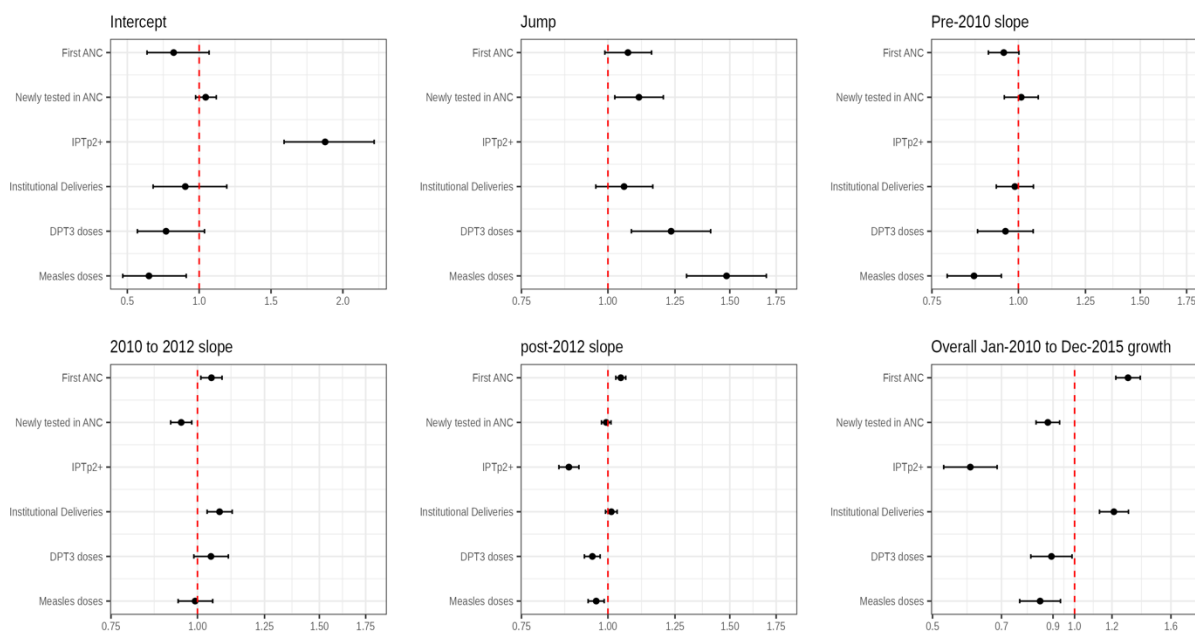


Figure 3.2. Sofala additional multiplicative change (RRR – ratio of relative ratios) relative to Manica

Table 8. Random-effects summary

indicator	RE SD		Variance Ratio
	district	health facility	
First ANC	0.2961 (0.2184 to 0.4130)	0.3212 (0.2449 to 0.4250)	0.3345 (0.0451 to 0.5367)
Newly tested in ANC	0.0334 (0.0211 to 0.0502)	0.0111 (0.0008 to 0.0246)	0.0354 (-0.0657 to 0.1266)
IPTp2+	0.1693 (0.1205 to 0.2408)	0.1330 (0.0812 to 0.1984)	0.1862 (-0.0584 to 0.3767)
Institutional deliveries	0.3195 (0.2341 to 0.4428)	0.5385 (0.3995 to 0.7247)	0.5075 (0.1961 to 0.6909)
DTP3 doses	0.2123 (0.1550 to 0.2974)	0.2792 (0.2063 to 0.3809)	0.0398 (-0.3705 to 0.3196)
Measles doses	0.2255 (0.1640 to 0.3145)	0.3310 (0.2471 to 0.4480)	0.0293 (-0.4040 to 0.3338)

RE SD - Random-effects Standard Deviation

Variance Ratio is estimated as $1 - \text{var_no_re} / \text{var_total}$, where var_no_re is the estimated variance of the posterior predictive distribution with random-effects set to 0, and var_total the estimated variance of the posterior predictive distribution reported by brms with the random effects.

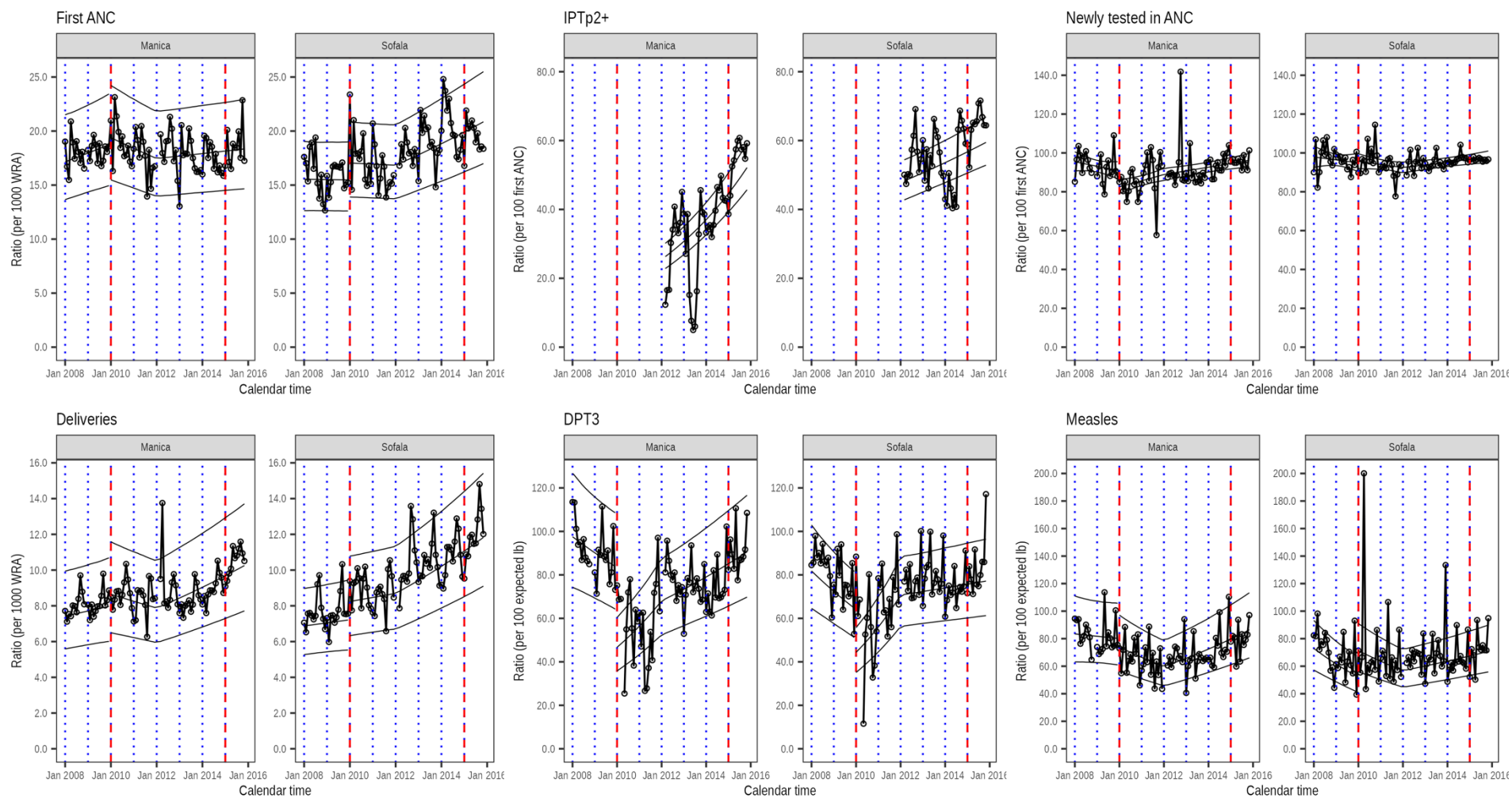


Figure 3.3 – Estimated model predictions overlapped to observed data

Discussion

As part of the Mozambique PHIT Partnership impact evaluation, we assessed the effectiveness of maternal and child health service provision between January 2010 and December 2015 by analyzing data from 185 health centers in two large provinces of central Mozambique, with Sofala Province as the intervention site and Manica Province as the control. Monthly counts of six maternal and child health care service provision indicators were selected according to data availability in the routine health information system and pre-established analysis framework. Indicator outcomes were analyzed at the health facility level and accounted for health center catchment size, secular and seasonality trends, using a controlled interrupted time series analysis.

Our findings showed mixed results. The PHIT Partnership in Mozambique was associated with improvements in service provision of first antenatal care visits and institutional delivery, but improvements in Sofala were outperformed by Manica in maternal HIV testing and IPTp2+ during antenatal care, and for long-term immunization services among children. However, these findings should be interpreted with caution. We were unable to account for health facility and district characteristics due to a lack of data at this level of analysis. In addition, we did not include data from outreach vaccination campaigns, which play an important role in vaccination services through the Expanded Programme on Immunization in Mozambique. Furthermore, although both Manica and Sofala provinces are at risk of flooding, many more areas of Sofala are prone to cyclical floods, contributing to a reduction in health services or total unavailability of health service provision at health facilities ²³.

The positive association between the PHIT Partnership in Mozambique and provision of antenatal care and institutional delivery provision is in line with described association between of utilization ANC and utilization of other maternal and child health care services. Antenatal care

visits represent an opportunity to promote the use of other maternal health services among women²⁴⁻²⁶. However, in this analysis, we did not find an association between the PHIT Partnership and newly HIV tested women in antenatal care services. This is not surprising given the already high rate of HIV testing, with more than 95 women tested per 100 ANC visits in both provinces. The malaria prevention in pregnancy is hard to interpret due to lack of secular data in our data. We have only data since January 2012.

Despite calls for rigorous evaluations of efforts to strengthen health systems, very few evaluations have used a comprehensive and holistic approach to assess the impact of interventions with system-wide effects. An evaluation that is broad and holistic focuses not just on one WHO health system building block, but many blocks simultaneously, because health systems are complex with many inter-connected parts^{27,28}. The Mozambique PHIT Partnership attempts to influence all health system building blocks, although it emphasizes three building blocks in particular—information, financing, and leadership and governance—by improving the use of routine data through appropriate tools that facilitate decision making by health system managers; strengthening management and planning capacity and funding district health plans; and strengthening capacity for operations research to guide systems strengthening efforts^{10,29}. Many of these activities have a long-term impact beyond the existence of the project. Moreover, the central idea of the Mozambique PHIT Partnership is to leverage and maximize the potential of existing tools, rather than imposing new tools out of the goals of the health system. For this reason, we use routine health information system data and we showed in elsewhere that the Mozambique PHIT Partnership activities improved data quality³⁰.

Limitations

Our analysis relied on data from Módulo Básico, the former health information system in Mozambique, which has since been replaced by SISMA, based on DHIS2. Módulo Básico required using Microsoft Access 2003, which was already outdated and had a complex and undocumented installation and upgrading process. Due to its decentralized nature and lack of security features, it was common for users to mistakenly enter health facility names incorrectly, with the potential for false duplications and missing data ³¹. We had record linked Módulo Básico to SISMA by health facility name to mitigate this situation. Our analysis lacks covariates to inform the model about the health facility and the district. The random-effects for each one of these levels show important heterogeneity for that particular level.

The catchment areas might be imprecise and particularly in the urban areas these tend to overlap whereas in rural areas these tend to be extensive and with lower density population. Although there is no public documentation on how the estimation process is conducted, we were informed that a joint team involving Ministry of Health and National Institute of Statistics members updated the population sizes around all health facilities in the country using information of neighborhoods around health facility from the 2017 Census. And then factors based on national proportion specific age and gender group is applied to obtain the target population (eg. under-5 children). Furthermore, the center of Mozambique is prone to cyclical floods and had military attacks which force the population to move and closure and damage of health facilities and infrastructure. Our analysis does not account for all these factors.

Conclusions

The Mozambique PHIT Partnership improved the provision of first antenatal care visits and institutional deliveries, but it did not improve beyond the control the provision of long term

immunization services at the health facility. Routine health information system is an important data source and can be leveraged for large health strengthening assessment.

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Supplementary materials

Tables

Table S1 - First ANC regression model coefficients

group	term	estimate	std.error	conf.low	conf.high
	(Intercept)	2.839581892	0.115915861	2.612755345	3.06351302
	post2010	0.029719158	0.03060107	-0.030180568	0.089473471
	timemon	0.003873245	0.001642121	0.000658355	0.007104716
	timepost.2010	-0.008240332	0.001973436	-0.012138968	-0.004384253
	timepost.2012	0.005448249	0.001535859	0.002447796	0.008448103
	fcsum.mes1	0.008722321	0.01285847	-0.016802128	0.034356018
	fcsum.mes2	0.0490452	0.012720545	0.024302327	0.074027792
	fcsum.mes3	0.045869763	0.012181026	0.022035182	0.069804965
	fcsum.mes4	0.047236097	0.012015629	0.023909593	0.070932984
	fcsum.mes5	0.053673569	0.011880058	0.030313066	0.076979241
	fcsum.mes6	0.042588541	0.011730008	0.019334768	0.065870331
	fcsum.mes7	0.02538825	0.011964439	0.001984409	0.048394438
	fcsum.mes8	-0.010419435	0.012061701	-0.033900329	0.013164037
	fcsum.mes9	-0.048501747	0.012045675	-0.072149275	-0.024874655
	fcsum.mes10	-0.065309143	0.012192441	-0.088993802	-0.041563569
	fcsum.mes11	-0.069947445	0.012044782	-0.093596479	-0.045997093
	f.provSofala	-0.19552136	0.130497155	-0.450695423	0.066799522
	post2010:f.provSofala	0.066557543	0.040225837	-0.010238119	0.145114871
	timemon:f.provSofala	-0.004053495	0.002160796	-0.008312276	0.000148443

	timepost.2010:f.provSofala	0.007928469	0.002620999	0.002795342	0.013038963
	timepost.2012:f.provSofala	-0.00030839	0.00201114	-0.004248038	0.003604427
fnum.dist	sd__(Intercept)	0.296133776	0.050255982	0.218392534	0.412958377
us_id	sd__(Intercept)	0.321156962	0.04603765	0.244899397	0.424986055

Estimated through a Negative Binomial regression with monthly first antenatal as the outcome and the estimated log-WRA as the offset.

WRA – women at reproductive age.

Table S2 - IPTp2+ regression model coefficients

group	term	estimate	std.error	conf.low	conf.high
	(Intercept)	-1.390074119	0.072044927	-1.5340514	-1.250895726
	timepost.2012	0.015558751	0.001126772	0.013336184	0.01776973
	fcsum.mes1	-0.090620752	0.030278164	-0.14932907	-0.031198269
	fcsum.mes2	-0.15166972	0.030200275	-0.209491237	-0.091975998
	fcsum.mes3	-0.009891787	0.029886084	-0.068244063	0.049897782
	fcsum.mes4	-0.081153675	0.030545573	-0.140324771	-0.020611584
	fcsum.mes5	-0.045904692	0.030267695	-0.104215663	0.013982357
	fcsum.mes6	-0.012494896	0.025921039	-0.063853513	0.038493485
	fcsum.mes7	0.073128882	0.026440105	0.021461767	0.124890892
	fcsum.mes8	0.137290205	0.026110027	0.086171442	0.189368242
	fcsum.mes9	0.10390803	0.024799816	0.055126194	0.152706902
	fcsum.mes10	0.05126179	0.024900924	0.002123794	0.100007886
	fcsum.mes11	0.001295799	0.025348647	-0.048609739	0.051577908
	f.provSofala	0.629466485	0.08417388	0.464294561	0.796485876
	timepost.2012:f.provSofala	-0.010825482	0.001402826	-0.01358774	-0.008043333
fnum.dist	sd__(Intercept)	0.169257025	0.030489993	0.120463406	0.240836733
us_id	sd__(Intercept)	0.133045147	0.03000979	0.081185953	0.198437983

Estimated through a Negative Binomial regression with monthly first antenatal as the outcome and the estimated log-WRA as the offset.

WRA – women at reproductive age.

Table S3 - Newly HIV tested in ANC services regression model coefficients

group	term	estimate	std.error	conf.low	conf.high
	(Intercept)	-0.096888248	0.025987367	-0.147688042	-0.046091091
	post2010	-0.09548391	0.030069899	-0.154882149	-0.036654349
	timemon	-0.002080576	0.001692571	-0.005422439	0.001253022
	timepost.2010	0.005167341	0.002000114	0.001202529	0.009053678
	timepost.2012	-0.001365753	0.001493357	-0.004287801	0.001603569
	fcsum.mes1	-0.013376951	0.012988625	-0.038653487	0.012193116
	fcsum.mes2	0.005141166	0.01315319	-0.020781143	0.030831549
	fcsum.mes3	0.004410153	0.012082592	-0.019192871	0.028075118
	fcsum.mes4	-0.004165648	0.012053931	-0.027454155	0.019343469
	fcsum.mes5	-0.012651739	0.011713773	-0.035636045	0.01058356
	fcsum.mes6	0.018893314	0.011654686	-0.004011968	0.041736317
	fcsum.mes7	0.003197369	0.011852796	-0.020050842	0.026654346
	fcsum.mes8	-0.004407952	0.011750389	-0.02721444	0.01861815
	fcsum.mes9	-0.036390154	0.011925337	-0.05976294	-0.012968798
	fcsum.mes10	0.039534083	0.011937486	0.016186996	0.063000421
	fcsum.mes11	-0.002228333	0.012292039	-0.026393212	0.022038762
	f.provSofala	0.044236033	0.035252633	-0.024958156	0.112591153
	post2010:f.provSofala	0.10316345	0.04114657	0.022899502	0.184305682
	timemon:f.provSofala	0.000791932	0.002422326	-0.003905755	0.005501184
	timepost.2010:f.provSofala	-0.0052977	0.002839867	-0.010761488	0.000298498
	timepost.2012:f.provSofala	0.004025807	0.001972828	0.000119485	0.007929605

fnum.dist	sd__(Intercept)	0.033360248	0.007468088	0.021058739	0.050186626
us_id	sd__(Intercept)	0.011120586	0.006224303	0.000848888	0.024617632

Estimated through a Negative Binomial regression with monthly first antenatal as the outcome and the estimated log-WRA as the offset.

WRA – women at reproductive age.

Table S4 – Deliveries regression model coefficients

group	term	estimate	std.error	conf.low	conf.high
	(Intercept)	1.883005174	0.145494677	1.599609294	2.176341612
	post2010	0.078821709	0.036606047	0.006573563	0.15001778
	timemon	0.00303569	0.001975419	-0.000815227	0.006928985
	timepost.2010	-0.006935487	0.002350332	-0.011624309	-0.00233453
	timepost.2012	0.00963226	0.00181416	0.006099207	0.013201179
	fcsum.mes1	-0.090335405	0.015501943	-0.120574998	-0.060192042
	fcsum.mes2	-0.121089791	0.015545074	-0.1511229	-0.090479601
	fcsum.mes3	-0.052472227	0.014665158	-0.081502869	-0.023402828
	fcsum.mes4	0.028565275	0.014172707	0.000989635	0.056404475
	fcsum.mes5	0.017522776	0.014204608	-0.010464322	0.045327613
	fcsum.mes6	-0.004620192	0.014154708	-0.032285113	0.023170935
	fcsum.mes7	-0.034813303	0.014244972	-0.062095305	-0.007004343
	fcsum.mes8	0.023958263	0.01408429	-0.003822904	0.051497713
	fcsum.mes9	0.193535621	0.013951196	0.166094863	0.220771439
	fcsum.mes10	0.096774176	0.014302895	0.068420603	0.124989766
	fcsum.mes11	0.007713201	0.014580557	-0.020744264	0.036628707
	f.provSofala	-0.101582467	0.141197815	-0.386358456	0.175761907
	post2010:f.provSofala	0.053660758	0.048496865	-0.040282537	0.149212201
	timemon:f.provSofala	-0.000980435	0.002633397	-0.006130068	0.004164913
	timepost.2010:f.provSofala	0.007110112	0.003138035	0.000981816	0.013255319
	timepost.2012:f.provSofala	-0.00518166	0.002351933	-0.009850695	-0.00055111

fnum.dist	sd__(Intercept)	0.319499682	0.054547257	0.234137983	0.442847054
us_id	sd__(Intercept)	0.538515936	0.082878085	0.399470445	0.72468007

Estimated through a Negative Binomial regression with monthly first antenatal as the outcome and the estimated log-WRA as the offset.

WRA – women at reproductive age.

Table S5 - DPT3 doses regression model coefficients

group	term	estimate	std.error	conf.low	conf.high
	(Intercept)	2.672121354	0.132424239	2.40515986	2.932203724
	post2010	-0.57857306	0.050802336	-0.678173158	-0.478129151
	timemon	-0.006576085	0.003011966	-0.012463687	-0.000667971
	timepost.2010	0.022292259	0.00354535	0.015374337	0.029161928
	timepost.2012	-0.009516219	0.002444298	-0.014274989	-0.004783522
	fcsum.mes1	0.045431858	0.022966168	0.000662053	0.090940782
	fcsum.mes2	0.028491586	0.022431105	-0.015369225	0.072383412
	fcsum.mes3	0.098206557	0.020270642	0.05927	0.138182604
	fcsum.mes4	-0.169383052	0.020617777	-0.210111727	-0.128495562
	fcsum.mes5	-0.01149257	0.019877893	-0.050317297	0.027142375
	fcsum.mes6	-0.055040944	0.020104299	-0.094303338	-0.015768707
	fcsum.mes7	0.012089045	0.019668928	-0.026163699	0.050760251
	fcsum.mes8	0.007686088	0.020069865	-0.031580864	0.047480924
	fcsum.mes9	-0.009074141	0.019974274	-0.047966352	0.030363744
	fcsum.mes10	-0.059699879	0.019976273	-0.099100878	-0.019822518
	fcsum.mes11	0.095804737	0.020892742	0.055220269	0.136817375
	f.provSofala	-0.261988463	0.152627323	-0.561923277	0.036406304
	post2010:f.provSofala	0.210206529	0.067673562	0.078049059	0.341762302
	timemon:f.provSofala	-0.003583416	0.003959908	-0.011322598	0.004104339
	timepost.2010:f.provSofala	0.007321401	0.004670126	-0.001838879	0.016289239
	timepost.2012:f.provSofala	-0.008051655	0.003229634	-0.014455528	-0.001784491

fnum.dist	sd__(Intercept)	0.339827821	0.056612564	0.250074549	0.4702372
us_id	sd__(Intercept)	0.339645759	0.050864277	0.256632633	0.453835345

Estimated through a Negative Binomial regression with monthly first antenatal as the outcome and the estimated log-WRA as the offset.

WRA – women at reproductive age.

Table S6 - Measles doses regression model coefficients

group	term	estimate	std.error	conf.low	conf.high
	(Intercept)	2.630913941	0.13949301	2.355907035	2.908537287
	post2010	-0.080760762	0.051017496	-0.180753326	0.020310825
	timemon	-0.001708833	0.002975651	-0.007530164	0.004180789
	timepost.2010	-0.007142862	0.00346191	-0.013980056	-0.000352574
	timepost.2012	0.016881907	0.002471294	0.012102541	0.021815088
	fcsum.mes1	-0.14733731	0.022238035	-0.190814093	-0.103837909
	fcsum.mes2	-0.074825196	0.02207227	-0.117592245	-0.031227023
	fcsum.mes3	0.002216477	0.019930725	-0.037397815	0.041674263
	fcsum.mes4	0.03369224	0.020271461	-0.006519848	0.074190998
	fcsum.mes5	0.11845307	0.019891884	0.079919082	0.15819619
	fcsum.mes6	-0.060669118	0.019980229	-0.099743902	-0.021843402
	fcsum.mes7	0.03793154	0.019733447	-0.000796456	0.076540691
	fcsum.mes8	0.000776381	0.020033275	-0.038256416	0.039953226
	fcsum.mes9	-0.000512705	0.019585787	-0.038342091	0.037828787
	fcsum.mes10	-0.080251799	0.019726251	-0.118661393	-0.041057279
	fcsum.mes11	0.11941123	0.020855576	0.078947484	0.160231381
	f.provSofala	-0.429960686	0.16798564	-0.758529068	-0.094390982
	post2010:f.provSofala	0.394590826	0.06733699	0.261605417	0.527000395
	timemon:f.provSofala	-0.012305249	0.003860784	-0.019737003	-0.004724108
	timepost.2010:f.provSofala	0.011663387	0.004549505	0.002758159	0.020515132
	timepost.2012:f.provSofala	-0.002610707	0.003263838	-0.009003025	0.003672217

fnum.dist	sd__(Intercept)	0.368226923	0.062745078	0.269088129	0.511289616
us_id	sd__(Intercept)	0.314508863	0.046935225	0.237489768	0.420687155

Estimated through a Negative Binomial regression with monthly first antenatal as the outcome and the estimated log-WRA as the offset.

WRA – women at reproductive age.

Table S7 – Predicted values for selected time points

indicator	province	pe.mean	lb	ub	period	what
dpt3_0yr	Manica	83.299	12.433	21.061	Dec 2009	PE
dpt3_0yr	Manica	46.706	6.979	11.771	Jan 2010	PE
dpt3_0yr	Manica	68.105	10.221	17.067	Jan 2012	PE
dpt3_0yr	Manica	91.145	13.685	22.877	Dec 2015	PE
dpt3_0yr	Manica	1.951	1.811	2.104		FD
dpt3_0yr	Sofala	64.100	9.857	15.769	Dec 2009	PE
dpt3_0yr	Sofala	44.349	6.842	10.856	Jan 2010	PE
dpt3_0yr	Sofala	70.738	10.974	17.231	Jan 2012	PE
dpt3_0yr	Sofala	77.296	11.957	18.836	Dec 2015	PE
dpt3_0yr	Sofala	1.743	1.628	1.864		FD
dpt3_0yr		0.893	0.808	0.988		DD
measles_0yr	Manica	80.083	11.857	20.606	Dec 2009	PE
measles_0yr	Manica	73.869	10.964	18.934	Jan 2010	PE
measles_0yr	Manica	59.731	8.907	15.314	Jan 2012	PE
measles_0yr	Manica	87.119	12.973	22.278	Dec 2015	PE
measles_0yr	Manica	1.179	1.095	1.270		FD
measles_0yr	Sofala	52.096	7.976	12.975	Dec 2009	PE
measles_0yr	Sofala	71.302	10.907	17.730	Jan 2010	PE
measles_0yr	Sofala	56.774	8.715	14.066	Jan 2012	PE
measles_0yr	Sofala	71.068	10.931	17.613	Dec 2015	PE
measles_0yr	Sofala	0.997	0.932	1.065		FD
measles_0yr		0.845	0.765	0.933		DD

ndeliveries	Manica	7.994	6.021	10.719	Dec 2009	PE
ndeliveries	Manica	8.649	6.492	11.586	Jan 2010	PE
ndeliveries	Manica	7.876	5.933	10.505	Jan 2012	PE
ndeliveries	Manica	10.312	7.758	13.785	Dec 2015	PE
ndeliveries	Manica	1.192	1.131	1.257		FD
ndeliveries	Sofala	7.221	5.538	9.458	Dec 2009	PE
ndeliveries	Sofala	8.244	6.329	10.787	Jan 2010	PE
ndeliveries	Sofala	8.698	6.696	11.333	Jan 2012	PE
ndeliveries	Sofala	11.906	9.153	15.523	Dec 2015	PE
ndeliveries	Sofala	1.444	1.378	1.514		FD
ndeliveries		1.211	1.129	1.300		DD
xcpn1	Manica	18.818	14.999	23.541	Dec 2009	PE
xcpn1	Manica	19.386	15.481	24.219	Jan 2010	PE
xcpn1	Manica	17.457	13.967	21.800	Jan 2012	PE
xcpn1	Manica	18.367	14.669	22.963	Dec 2015	PE
xcpn1	Manica	0.947	0.906	0.990		FD
xcpn1	Sofala	15.476	12.606	19.020	Dec 2009	PE
xcpn1	Sofala	17.040	13.895	20.848	Jan 2010	PE
xcpn1	Sofala	16.840	13.733	20.581	Jan 2012	PE
xcpn1	Sofala	20.952	17.067	25.610	Dec 2015	PE
xcpn1	Sofala	1.230	1.180	1.280		FD
xcpn1		1.298	1.223	1.377		DD
anc_hivtested	Manica	90.822	0.863	0.956	Dec 2009	PE
anc_hivtested	Manica	82.551	0.791	0.863	Jan 2010	PE

anc_hivtested	Manica	88.899	0.858	0.921	Jan 2012	PE
anc_hivtested	Manica	96.388	0.930	1.000	Dec 2015	PE
anc_hivtested	Manica	1.168	1.119	1.218		FD
anc_hivtested	Sofala	94.930	0.904	0.997	Dec 2009	PE
anc_hivtested	Sofala	95.661	0.919	0.996	Jan 2010	PE
anc_hivtested	Sofala	92.458	0.897	0.952	Jan 2012	PE
anc_hivtested	Sofala	98.012	0.950	1.012	Dec 2015	PE
anc_hivtested	Sofala	1.025	0.985	1.066		FD
anc_hivtested		0.877	0.829	0.929		DD
ipt2	Manica	25.489	0.221	0.293	Jan 2012	PE
ipt2	Manica	52.958	0.464	0.604	Dec 2015	PE
ipt2	Manica	2.078	1.872	2.305		FD
ipt2	Sofala	47.832	0.423	0.539	Jan 2012	PE
ipt2	Sofala	59.750	0.531	0.672	Dec 2015	PE
ipt2	Sofala	1.249	1.154	1.350		FD
ipt2		0.601	0.528	0.685		DD

PE – point estimate

FD – First difference in this case is a relative difference within each province between January 2010 and December 2015

DD – Relative difference of first differences

Figures

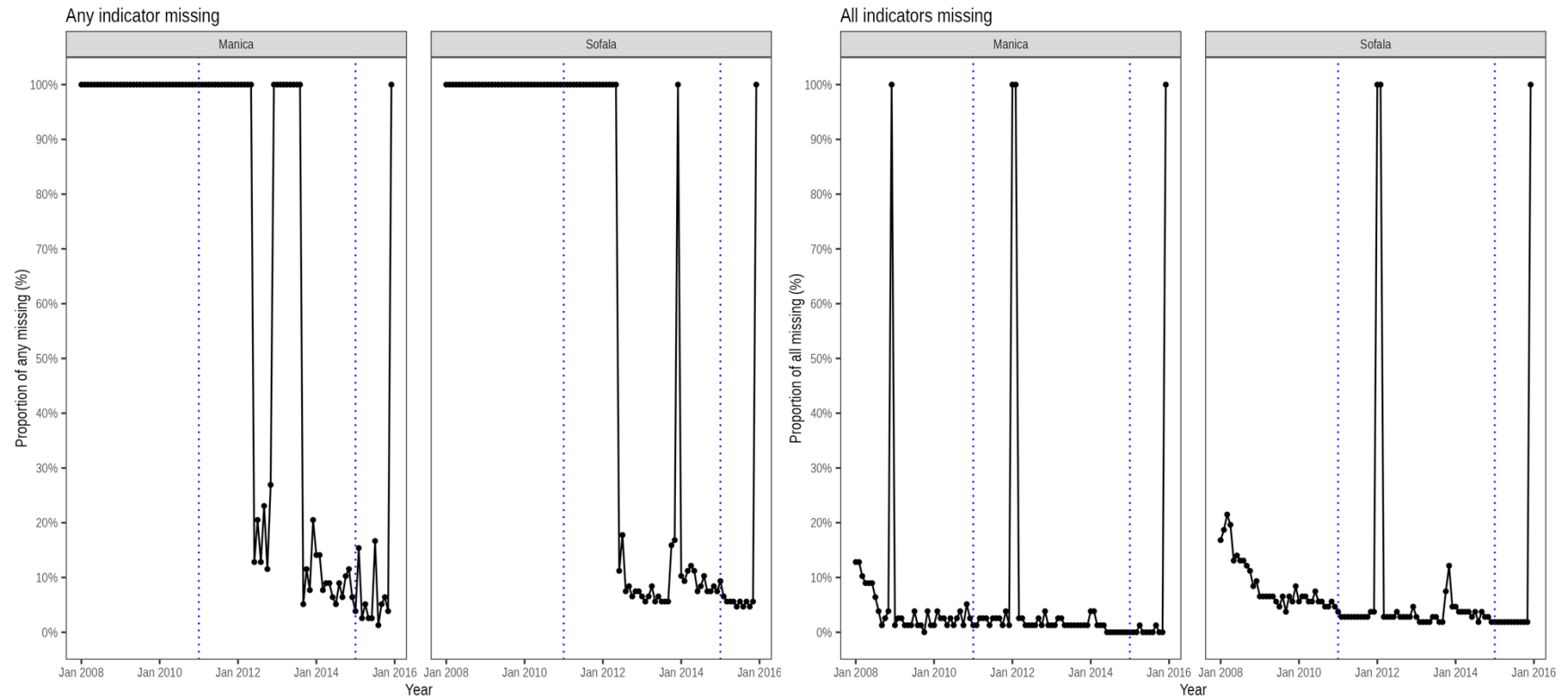


Figure S1 – Monthly proportion of missing observations of the 6 indicators.

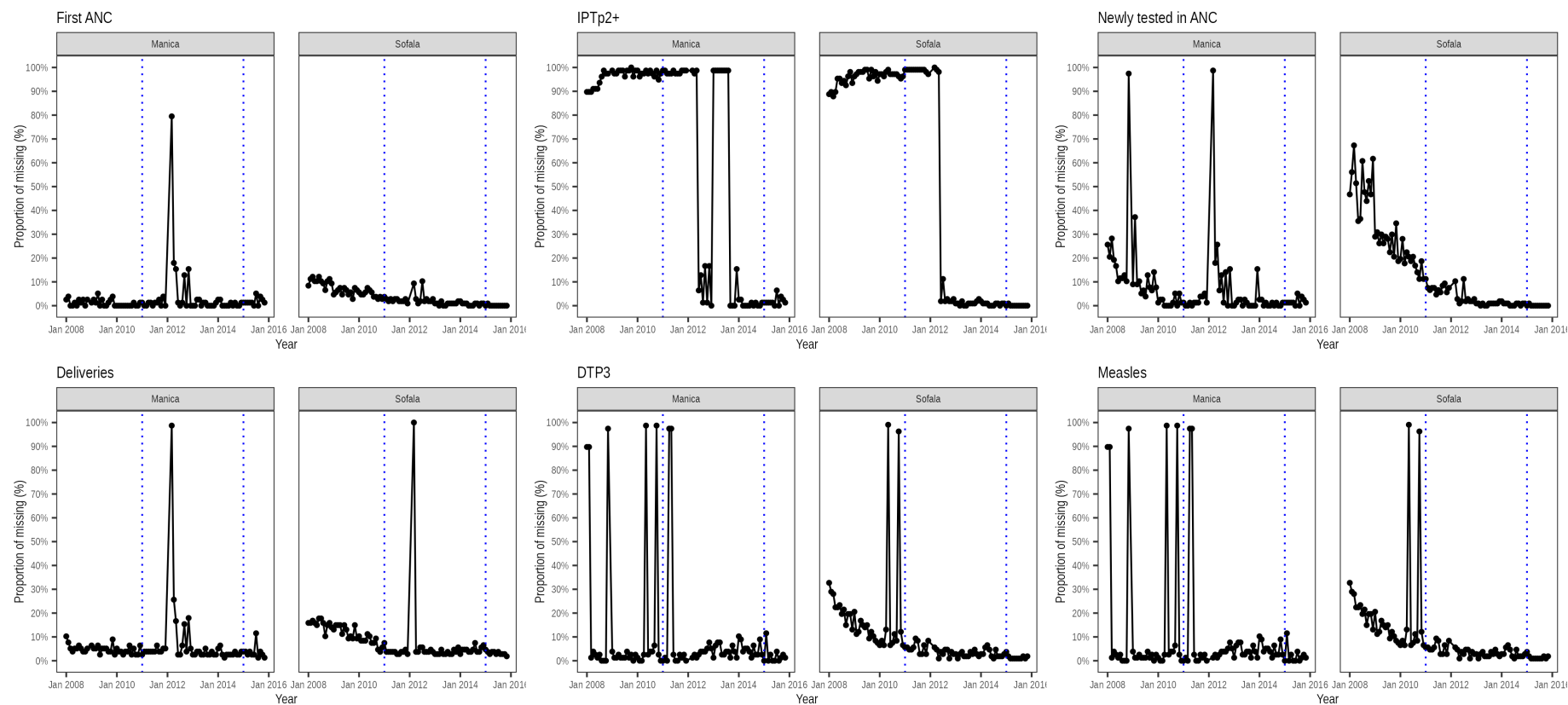


Figure S2 – Monthly proportion of missing observations per indicator and province.

Chapter 4: Early Effects of COVID-19 on Maternal and Child Health Service Disruption in Mozambique

CHAPTER 4: EARLY EFFECTS OF COVID-19 ON MATERNAL AND CHILD HEALTH SERVICE DISRUPTION IN MOZAMBIQUE

Orvalho Augusto^{1,2}, Tim Robertson³, Quinhas Fernandes^{1,4}, Sérgio Chicumbe⁵, Ivalda Macicame⁵, Ivan Manhiça⁴, Stélio Tembe^{1,6}, Bradley H. Wagenaar^{1,7}, Laura Anselmi⁸, Jon Wakefield^{9,10}, Kenneth Sherr^{1,7,11}

¹Department of Global Health, School of Public Health, University of Washington, Seattle, USA

²Eduardo Mondlane University, Maputo, Mozambique

³Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD, USA

⁴National Directorate of Public Health, Ministry of Health, Mozambique

⁵National Institute of Health, Ministry of Health, Mozambique

⁶Direcção Provincial de Inhambane, Mozambique

⁷Department of Epidemiology, School of Public Health, University of Washington, Seattle, USA

⁸Health Organization, Policy and Economics, Centre for Primary Care and Health Services Research, University of Manchester

⁹Department of Biostatistics, School of Public Health, University of Washington, Seattle, USA

¹⁰Department of Statistics, University of Washington, Seattle, USA

¹¹Department of Industrial & Systems Engineering, University of Washington, Seattle, USA

*** Correspondence:** Orvalho Augusto, orvaquim@gmail.com

ORCID: 0000-0002-0005-3968

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Abstract

Introduction

After the World Health Organization declared COVID-19 a pandemic, more than 184 million cases and 4 million deaths had been recorded worldwide by July 2021. These are likely to be underestimates and do not distinguish between direct and indirect deaths resulting from disruptions in health care services. The purpose of our research was to assess the early impact of COVID-19 in 2020 and early 2021 on maternal and child healthcare service delivery at the district level in Mozambique using routine health information system data, and estimate associated excess maternal and child deaths.

Methods

Using data from Mozambique's routine health information system (SISMA, Sistema de Informação em Saúde para Monitoria e Avaliação), we conducted a time-series analysis to assess changes in nine selected indicators representing the continuum of maternal and child health care service provision in 159 districts in Mozambique. The dataset was extracted as counts of services provided from January 2017 to March 2021. Descriptive statistics were used for district comparisons, and district-specific time-series plots were produced. We used absolute differences or ratios for comparisons between observed data and modeled predictions as a measure of the magnitude of loss in service provision. Mortality estimates were performed using the Lives Saved Tool (LiST).

Results

All maternal and child health care service indicators that we assessed demonstrated service delivery disruptions (below 10% of the expected counts), with the number of new users of family planning and malaria treatment with Coartem (number of children under five treated) experiencing

the largest disruptions. Immediate losses were observed in April 2020 for all indicators, with the exception of treatment of malaria with Coartem. The number of excess deaths estimated in 2020 due to loss of health service delivery were 11,337 (12.8%) children under five, 5,705 (11.3%) neonates, and 387 (7.6%) mothers.

Conclusion

Findings from our study support existing research showing the negative impact of COVID-19 on maternal and child health services utilisation in sub-Saharan Africa. This study offers subnational and granular estimates of service loss that can be useful for health system recovery planning. To our knowledge, it is the first study on the early impacts of COVID-19 on maternal and child health care service utilisation conducted in an African Portuguese-speaking country.

Keywords: COVID-19, Maternal-Child Health Services, Mozambique, Interrupted Time Series Analysis, LMIC, Portuguese-speaking African countries

Introduction

As of July 6, 2021, 15 months after the World Health Organization (WHO) declared the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) a global pandemic, there were more than 184 million cases, resulting in 4 million deaths worldwide (1). By December 31, 2020, 3 million deaths had been recorded worldwide, corresponding to 1.2 million excess deaths in 2020. However, these are likely to be underestimates (2). Moreover, it is challenging to distinguish between direct and indirect deaths as a result of potential service disruption due to the COVID-19 pandemic. Early forecasts from May 2020 estimated a 9.8% to 44.7% increase in under-five child deaths and an 8.3% to 38.6% increase in maternal deaths per month due to service disruption of several maternal and child interventions in 118 low-income and middle-income countries (3).

Mozambique reported its first case of COVID-19 on March 22, 2020, with 80,888 cases reported resulting in 912 deaths as of July 6, 2021 (4). Two major outbreak waves were observed between March 2020 and April 2021, and a third wave occurred between June and September 2021. The third wave was dominated by the delta variant, with many reported cases and a higher fatality rate; however, by that time the country had vaccinated health care workers and had begun to vaccinate other major risk groups (e.g., older adults over 60 years) and had increased capacity for diagnosis and management of severe COVID-19 cases.

Early in the epidemic Mozambique established a scientific committee to guide and counsel the government's COVID-19 response, mounted a surveillance system for SARS-CoV-2 infection, and enacted a six-month state of emergency beginning April 1, 2020 that included a range of measures to limit the spread of infections including a) actions for personal protection (e.g., promotion of hand washing and enforcement of face mask wearing), b) social measures and prohibition of public gatherings (social distancing; closing schools, churches, beaches, and gyms;

reducing the number of workers; and instituting curfews), c) travel restrictions, d) environmental measures (e.g. disinfection of surfaces frequently touched) (5,6). These actions—combined with a general public fear of contracting SARS-CoV-2 and misinformation about the source and treatment of COVID-19—potentially led to lower rates of health service utilisation (3,7).

Health information systems are core components of functional health systems as they ensure the production, analysis, dissemination and use of reliable and timely information on health service utilization, health determinants and health status (8,9). Routine health information systems (RHIS) provide regular, repeated data that is multilevel (including data from primary care facilities to differentiated care) that can be used to establish utilization patterns and to detect deviations from these patterns that can be used to describe the magnitude and duration of disruptions to health service utilization. Such assessments are essential to plan for health service recovery, including monitoring the effects of corrective interventions (9).

The purpose of our research was to assess the early impact (2020 and early 2021) of COVID-19 on utilization of maternal and child health services at the district level in Mozambique based on routine health information system data. In addition, we aimed to estimate excess maternal and child mortality due to these losses.

Materials and Methods

Study design

Using data from the country's routine health information system (SISMA, *Sistema de Informação em Saúde para Monitoria e Avaliação*), we conducted a time-series analysis to assess changes in selected indicators of maternal and child health care service provision in all districts of Mozambique in 2020 to March 2021, before widespread detection of the delta variant.

Routine health data are collected primarily via paper registers at health facilities and aggregated in monthly reports at the district level. These reports are then entered into SISMA. The dataset used for our analysis was extracted as counts of services provided from January 2017 to March 2021 for each of Mozambique's 159 districts. Since October 2019, there has been military conflict

Box

Since October 2017, the northern province of Cabo Delgado has been under armed nonstate group attacks. During 2020 there was an escalation of the attacks with brutal attacks towards civilians, setting fire to homes, shops, schools, and religious and government buildings, and forcing people to flee into the bush and neighboring villages and provinces. Between April 2020 and April 2021, the number of internally displaced people (IDP) increased from 172,000 to 732,000. Around 72% of the displaced live with host communities, while 28% are in IDP camps.

Box 1 – Cabo Delgado Province under military attack (10)

affecting vast areas of Cabo Delgado Province, leading to unprecedented population loss and displacement, as well as the destruction and closure of health facilities. We therefore decided to remove data from the Cabo Delgado Province from our analysis (box 1).

Study setting and overview of Mozambique and its health system

Mozambique is in southeastern Africa (Figure 4.1), with a surface area of 801,590 km² and 2,700 km of coastal line. It is crossed from west to east by large rivers, isolating parts of the country during the rainy season (between October and March), a situation that is worsening with climate change. Administratively, the country is divided into 11 provinces. Apart from Maputo City and

Maputo Province, each province is divided into approximately 15 districts, with a total of 159 districts in the country. The 2017 National Census recorded 26,899,105 inhabitants, with a median age of 16.6 years, life expectancy at birth of 53.7 years, and an estimated 2.8% yearly population growth rate (11). Children under five and women of reproductive age (ages 15 to 49) corresponded to 34.6% and 23.8% of the population, respectively. Overall Mozambique has a low population density, with 34.1 inhabitants per km², except for Maputo City where the density is 3,107.1 inhabitants per km² (Table 4.1). In 2019 the infant mortality ratio (IMR) was estimated at 51.0 deaths per 1,000 live births – among the 20 highest globally even after an average annual decrease of 2.6% since 1990 (12). The maternal mortality ratio was estimated at 289 deaths per 100,000 live births in 2017, the 3rd worst figure among the 16 nations in SADC (Southern African Development Community) region and one of the top 20 high in sub-Saharan Africa (13). Mozambique is a low-income country with a gross national income per capita in 2019 of US\$504 (14). Mozambique ranks 181 out of 189 countries assessed in the Human Development Index(15).

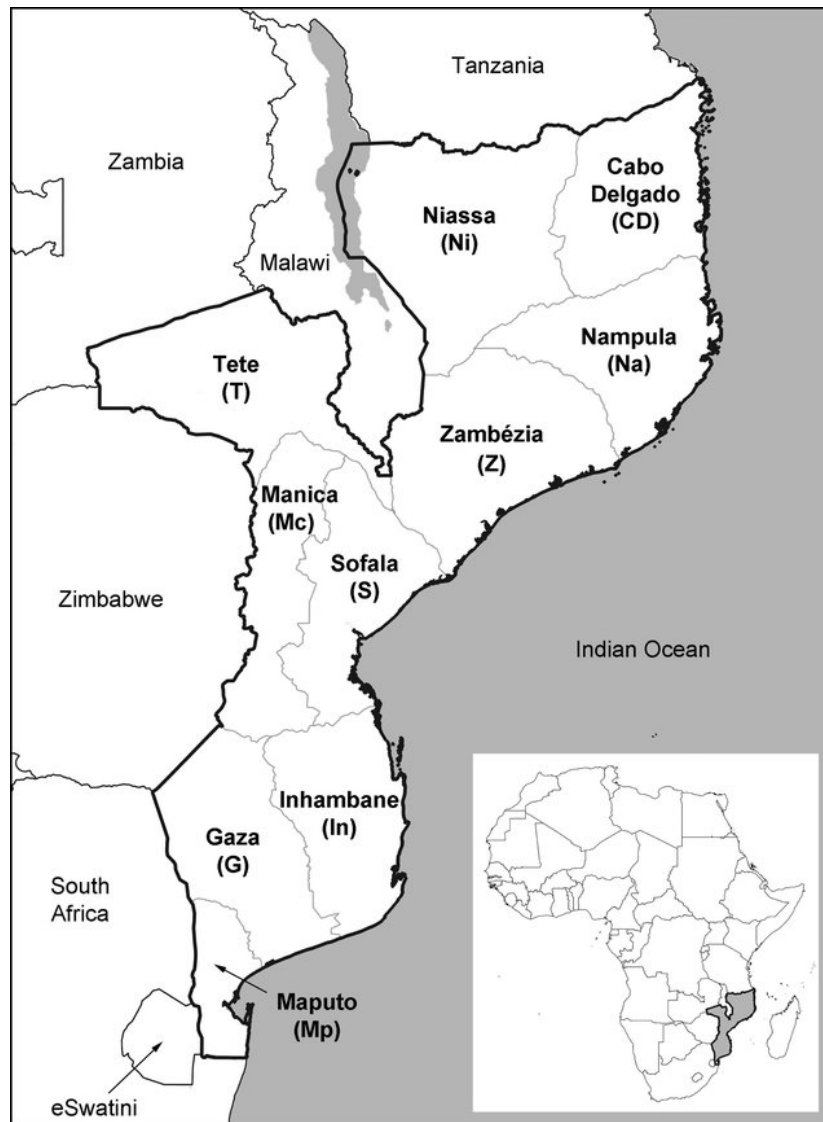


Figure 4.1 - Map of Mozambique with administrative divisions (provinces). Maputo City (not in the illustration) is contained within Maputo Province. Source: Darbyshire et al 2019.

The national health system provides nearly all health care services throughout the country, whereas private sector facilities are available primarily in Maputo City and a few provincial capitals. The national health system is divided into four levels of progressively more complex care. (1) The primary level (health centers or posts) provides primary care, including basic maternal and child health services in most facilities. (2) Secondary level facilities (rural, district, or general hospitals)

are located at the district level, and serve as referral facilities for primary level facilities (note that some secondary level hospitals may include surgical services such as cesarean sections). (3) The tertiary level consists of hospitals located in provincial capitals, acting as referral facilities for the province. (4) The quaternary level (central hospitals) serve as regional (North, Center, or South) referral facilities (16).

Table 4.1. Mozambique demographic characteristics by province

Province	Population	Women (%) [*]	Women of Reproductive Age (%) [*]	Children Under 5 (%) [*]	Population Density (Inhabitants/km ²)	Crude Birth Rate	Number of Districts
Cabo							
Delgado†	2,267,715	51.6	22.8	35.5	29.0	39.6	17
Gaza	1,388,039	54.8	24.7	28.1	18.4	31.6	14
Inhambane	1,454,804	54.3	24.5	26.4	21.1	28.8	14
Manica	1,851,931	52.1	23.5	36.0	29.6	44.0	12
Maputo City	1,080,277	51.7	29.0	20.8	3,107.1	24.5	1‡
Maputo							
Province	1,908,078	52.2	27.7	24.6	81.8	30.3	8
Nampula	5,483,382	51.5	22.8	38.6	69.9	38.2	23
Niassa	1,713,751	51.4	22.2	39.7	13.2	41.9	19
Sofala	2,196,845	51.7	23.9	33.5	32.3	40.7	13
Tete	2,551,826	51.2	22.9	35.6	25.3	38.0	15
Zambézia	5,002,457	52.1	23.1	38.6	48.4	43.3	23
Total	26,899,105	52.0	23.8	34.6	34.1	37.9	159

^{*} proportions over total population

† Cabo Delgado was excluded from analysis due to insecurity and military conflict affecting the region.

‡ Maputo City has seven municipal districts. Municipal districts are not equivalent to districts as in other provinces.

Data sources and processing

Monthly data on health service provision at the district level were extracted from SISMA in April 2021 following a request from the National Directorate of Public Health (DNSP, Direcção Nacional de Saúde Pública) to assess the impact of COVID-19 on maternal and child health routine indicators. The population data (total women of reproductive age and children under five) were extracted from Government of Mozambique projections using the 2017 National Census [7].

A set of nine indicators were selected based on data availability, completeness, and whether the indicators could be used in the Lives Saved Tool (LiST) (17) for mortality estimation. The indicators included are: (1) number of women who attended first antenatal care visits; (2) number of institutional deliveries; (3) number of visits for measles vaccination; (4) number of visits for third dose of DPTH (diphtheria, pertussis, tetanus toxoid combined with hepatitis B) vaccination; (5) number of postnatal care visits within 48 hours after delivery; (6) number of postnatal care visits within three to seven days after delivery; (7) number of visits for treatment of malaria with Coartem for children under five; (8) number of first well-child visits; and (9) number of new family planning users. Data completeness was assessed as the proportion of district-months without missing information. Indicators missing fewer than 10% district-months were kept for analysis (Table 4.2) with two exceptions —treatment of malaria with Coartem and first well-child visit. These indicators were retained as measures of child health care utilization are required to estimate mortality using LiST. The team agreed that the data were sufficiently reliable to use for mortality estimation, and that while there would be greater uncertainty in LiST findings, they would still provide important guidance.

Statistical analysis

The outcome of our analysis were the service utilization counts for each indicator, aggregated at the district level. We conducted an exploratory analysis to assess data completeness, identify potential outliers, and determine the model parametrisation type. Descriptive statistics (mean, standard deviation, coefficient of variation, median, first and third quartile, and proportion) were used for district comparisons, and district-specific time-series plots were produced to select the final model parametrisation. Given higher unpredictability in trends in 2020 and 2021, we modelled linear trends using data prior to 2020. We then used the model predictions for each month in 2020 and the first quarter of 2021. We compared the observed counts with the expected (predicted) counts as absolute differences and ratios to provide a measure of the magnitude of loss in service provision for maternal and child health services as a result of COVID-19.

To model the data prior to 2020, we used a hierarchical negative binomial regression model with district- and province-level random effects for intercepts and district-level slopes. A negative binomial model was chosen to accommodate count outcome data with potentially greater variability than a common Poisson model. The hierarchical model addresses that districts are nested within provinces (i.e at the highest level is the between-province variability); the multiple observations per district (i.e between districts variability); and month-to-month within-district variability. In addition, we account for annual seasonality variability. The model has the following parametrisation:

$$\begin{aligned} \log(count_{dt}) = & (\beta_0 + b_0^{*d} + b_0^{*p}) + (\beta_1 + b_1^{*d}) \cdot t \\ & + \sum_{m=2}^{12} \delta_m \cdot I(Month_t = m) + 1 \cdot [\log(Population_{dt})] \end{aligned}$$

where *count* is the count of service delivery from a district *d* at time *t*. The variable and subscript *t* variable *time* index time in months from January 2017 through December 2019. The parameters

of interest are the β 's and b 's. The β_0 represents in log-scale the overall district average counts in January 2017, whereas the b_0^{*d} and b_0^{*p} are deviations of a particular district d and province p , respectively. The β_1 represents in log-scale the monthly average increase with b_1^{*d} a particular district deviation. The summation with δ and $I(\text{Month}_t = m)$ are dummy indicator variables to capture monthly seasonal deviations from a January month. To account for the differences in district populations, district population is introduced as an offset (an independent variable in the model without a coefficient estimated) in the model. All regression models were estimated through the Bayesian framework using Stan programming language in the brms package (18) of R version 3.6.3 (19). The software default priors (uninformative and diffuse priors) were found to be appropriate for this analysis after the number of iterations was increased to 20,000 (5,000 per chain), and a thinning interval of 5 and 1,000 observations in the burn-up period. From the posterior distribution, 10,000 realisations of the sets of parameters were obtained and used to estimate the absolute and relative loss of service delivery for each month in 2020 and the first quarter of 2021.

Mortality estimates were performed using the LiST, [11] which is a mathematical model that uses community-level maternal and child health service data as inputs to estimate maternal and child mortality. We used coverage estimates from the 2015 Immunization, Malaria and HIV/AIDS Indicator Survey (20) and the 2011 Demographic and Health Survey (21) as inputs for service coverage data. Changes in health service utilization were estimated using RHIS data aggregated at the district level, which is assumed to reflect the experience of district populations given the high utilization of maternal and child health services through the public sector, as well as infrequent population migration in Mozambique.

Ethical considerations

For this study we used district-level aggregated data, with approval from the Ministry of Health. We extracted data from the routine health information system (SISMA). Because routine data do not contain personal identifiers, ethical approval was deemed unnecessary. However, the National Directorate of Public Health approved the use of the data.

Results

Trends before 2020

From January 2017 through December 2019, with the exception of Cabo Delgado Province, 140 districts reported data. Table 4.2 describes the selected maternal and child health indicators prior to January 2020. On average (standard deviation), a typical district per month reported 854 new first antenatal care consults, 571 institutional deliveries, 507 postnatal visits within 48 hours after delivery, 87 postnatal visits within three to seven days after delivery, and 604 visits for a third dose of the combined diphtheria, pertussis, tetanus, and haemophilus influenza (DPTH3) vaccine. However, there is a large district-level variation with the coefficients of variation (CV) being at least 75%, i.e., for each indicator the standard deviation is above three quarters of its mean, and reaching above 100% among the monthly counts of post-antenatal care visits, malaria treatment with Coartem and first well-child visits. Antenatal care visits, institutional deliveries, measles and DPTH3 doses, and postnatal care visits within 48 hours of delivery saw a relative annual growth of about 5%, whereas the other indicators saw a smaller magnitude year descending trend. The number of family planning new users remained stable in the years before COVID-19.

Table 4.2. Selected maternal and child health indicators for analysis between January 2017 and December 2019 (district-month counts)

Indicator	Number of observations	Missing (%)	Minimum	Maximum	Mean	SD	CV	Relative annual growth (%)*
Antenatal care (first visit)	4,895	5 (0.1)	6	5,577	854	656	0.77	4.5
Institutional delivery	4,899	1 (0.0)	5	3,336	571	429	0.75	5.4
Measles vaccination	4,895	5 (0.1)	3	7,563	604	488	0.81	4.8
DPTH3 vaccination	4,895	5 (0.1)	4	8,549	604	479	0.79	6.1
Postnatal care visit (within 48 hours)	4,897	3 (0.1)	5	2,248	507	375	0.74	8.2
Postnatal care visit (within 3 to 7 days)	4,545	355 (7.8)	1	1,138	87	107	1.23	-3.3
Treatment of malaria with Coartem (children under 5) [†]	1,476	204 (13.8)	0	9,270	1,322	1,347	1.02	-1.6
First well-child visit [†]	1,502	178 (11.9.6)	0	7,436	1,286	1,790	1.39	-4.6
Family planning (new users) [¶]	3,219	1 (0.0)	19	10,350	1,503	1,449	0.96	0.7

SD - standard deviation

CV - coefficient of variation (the ratio of the SD to the mean)

DPTH3 - third dose of diphtheria, pertussis, tetanus, and haemophilus influenza vaccine

* Estimated from a generalized linear model regression with family quasipoisson and log-link for descriptive purposes

[†] No data available on SISMA before January 2019

[¶] No data available on SISMA before January 2018

Table 4.3 shows the regression coefficients for service provision counts per 1,000 inhabitants (except for the first well-child visits, which is in counts per 100,000 children) between January 2017 and December 2019, accounting for population size and seasonality. Except for postnatal care visits (within three to seven days) and first well-child visits, all indicators had a relative

growth of 2% to 7% per year, apart from treatment of malaria with Coartem for children under age five, which reached 35% increase per year. The standard deviation of the random effects illustrates heterogeneity between districts (district random intercept) and provinces (province random intercept) as well as the trajectory of the indicators over time (district random slope).

Table 4.3. Mixed-effect negative binomial regression coefficients for selected indicators, January 2017 to December 2019

Indicator	Intercept (per 1,000 inhabitants)	Time (year)	$\sigma_{\text{district_intercept}}^*$	$\sigma_{\text{district_slope}}^*$	$\sigma_{\text{province_intercept}}^*$
Antenatal care (first visit)	7.92 [6.56 - 9.60]	1.02 [1.01 - 1.03]	0.203 [0.178; 0.233]	0.045 [0.038; 0.053]	0.283 [0.165; 0.512]
Institutional delivery	5.42 [4.57 - 6.40]	1.03 [1.02 - 1.04]	0.245 [0.215; 0.280]	0.049 [0.042; 0.057]	0.244 [0.133; 0.435]
Measles vaccination	5.89 [5.09 - 6.81]	1.02 [1.00 - 1.03]	0.199 [0.172; 0.230]	0.053 [0.043; 0.064]	0.196 [0.104; 0.353]
DPTH3 vaccination	5.87 [5.04 - 6.82]	1.02 [1.01 - 1.03]	0.180 [0.157; 0.207]	0.036 [0.028; 0.045]	0.216 [0.121; 0.381]
Postnatal care visit (within 48 hours)	4.64 [3.69 - 5.78]	1.05 [1.03 - 1.06]	0.299 [0.261; 0.342]	0.074 [0.064; 0.086]	0.334 [0.188; 0.587]
Postnatal care visit (within 3 to 7 days)	0.83 [0.69 - 0.99]	0.88 [0.83 - 0.94]	0.641 [0.556; 0.736]	0.312 [0.269; 0.363]	0.158 [0.007; 0.440]
Treatment of malaria with Coartem (children under 5) [†]	8.13 [2.83 - 25.37]	1.35 [1.21 - 1.49]	0.635 [0.539; 0.744]	0.277 [0.225; 0.335]	0.299 [0.069; 0.625]
First well-child visit [†]	18.82 [14.32 - 25.25]	0.89 [0.82 - 0.96]	0.545 [0.394; 0.689]	0.219 [0.152; 0.288]	1.656 [1.019; 2.775]
Family planning (new user) [¶]	14.87 [12.00 - 18.44]	1.04 [1.02 - 1.07]	0.369 [0.273; 0.468]	0.139 [0.096; 0.181]	0.398 [0.214; 0.715]

* Standard deviations of the random effects are on the log scale.

[†] Data available on SISMA since January 2019. First well-child visits are measured per 100,000 children under five.

[¶] Data available on SISMA since January 2018.

The intercept indicates the average rate (counts per 1000 inhabitants) on January 2017. The time coefficient indicates the increasing factor per year (eg: the antenatal care visits rate increases 1.02 times in a year). The sigmas are an indication of the source of variability for the intercept and slope.

Service disruptions

Table 4.4 shows the observed and expected service counts in 2020 and for the first quarter of 2021. We estimated relative losses for all service provision indicators at the national level. Our findings show that all services experienced losses, but the services most affected were family planning (number of new users) and malaria treatment with Coartem (number of children under five treated), which showed relative losses of more than a quarter (29.87% and 29.62%, respectively) compared with what was expected. Other services sustained losses of less than 10% of what was expected in 2020, with substantial increases in losses during the first quarter of 2021.

The monthly ratio of observed counts to expected counts reveals immediate losses in April 2020 (Table 4.5) for nearly all indicators, with ratios below 0.90. Most of those indicators had sustained losses (ratios below 0.95) for more than three months, except for first antenatal care visits and first well-child visits. However, these patterns varied slightly by province (Supplemental Figures FS1 through FS9). The provinces of Manica, Maputo City, Nampula, and Sofala experienced the most severe losses in the number of family planning new users.

Table 4.4. Mozambique observed and expected service losses by indicator, 2020 and first quarter of 2021

Indicator	2020				First Quarter 2021				Overall			
	Observed	Expected	Difference	Percentage Loss (%)*	Observed	Expected	Difference	Difference (%)*	Observed	Expected	Difference	Percentage Loss (%)*
Antenatal care (first visit)	1,752,157	1,787,674	-35,517	-1.99	446,890	475,221	-28,331	-5.96	2,199,047	2,262,894	-63,847	-2.82
Institutional delivery	1,169,966	1,223,790	-53,823	-4.40	298,712	312,064	-13,351	-4.28	1,468,679	1,535,853	-67,174	-4.37
Measles vaccination	1,164,151	1,254,650	-90,498	-7.21	268,441	301,688	-33,248	-11.02	1,432,592	1,556,338	-123,746	-7.95
DPTH3 vaccination	1,164,712	1,274,312	-109,599	-8.60	224,389	309,538	-85,149	-27.51	1,389,102	1,583,850	-194,748	-12.30
Postnatal care visit (within 48 hours)	1,053,793	1,149,645	-95,852	-8.34	266,587	294,773	-28,186	-9.56	1,320,381	1,444,418	-124,037	-8.59
Postnatal care visit (within 3 to 7 days)	159,760	160,383	-623	-0.39	38,513	43,899	-5,387	-12.27	198,273	204,283	-6,010	-2.94
Treatment of malaria with Coartem (children under 5)	2,815,039	3,685,427	-870,389	-23.62	645,443	1,231,383	-585,940	-47.58	3,460,482	4,916,811	-1,456,329	-29.62
First well-child visit	2,145,752	2,334,514	-188,763	-8.09	-	559,308	-	-	-	2,893,823	-	-
Family planning (new user)	2,229,723	3,240,669	-1,010,946	-31.20	533,932	700,080	-166,148	-23.73	2,763,655	3,940,749	-1,177,094	-29.87

The observed counts in the table are slightly different from the raw data, because here we computed first the average (per indicator) then multiplied by 159 (total number of districts) to account for districts with missing information.

The expected counts are estimates from the model for each parameter.

* The Percentage loss is computed as $100 \times (\text{observed} - \text{expected}) / \text{expected}$.

Table 4.5. National-level relative reduction in service counts by indicator and month, 2020 and first quarter of 2021

Indicator	2020												2021		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Antenatal care (first visit)	0.96	0.99	1.03	0.87	0.99	0.95	1.00	1.08	0.98	1.08	1.01	0.90	1.07	0.96	1.01
	(0.88 - 1.04)	(0.91 - 1.08)	(0.95 - 1.13)	(0.79 - 0.95)	(0.90 - 1.09)	(0.86 - 1.04)	(0.90 - 1.10)	(0.97 - 1.19)	(0.88 - 1.08)	(0.96 - 1.20)	(0.90 - 1.13)	(0.80 - 1.01)	(0.95 - 1.20)	(0.85 - 1.09)	(0.89 - 1.14)
Institutional delivery	0.95	1.04	1.02	0.78	0.66	0.82	0.91	0.98	1.07	1.11	1.07	1.05			
	(0.73 - 1.22)	(0.79 - 1.34)	(0.77 - 1.34)	(0.58 - 1.03)	(0.49 - 0.90)	(0.59 - 1.11)	(0.66 - 1.25)	(0.70 - 1.37)	(0.75 - 1.50)	(0.77 - 1.58)	(0.73 - 1.54)	(0.71 - 1.54)			
Measles vaccination	0.99	1.01	1.02	0.84	0.92	0.85	0.94	0.96	0.88	0.96	0.87	0.88	0.92	0.81	0.83
	(0.90 - 1.09)	(0.91 - 1.11)	(0.92 - 1.13)	(0.75 - 0.93)	(0.82 - 1.02)	(0.76 - 0.95)	(0.83 - 1.05)	(0.85 - 1.08)	(0.77 - 0.99)	(0.84 - 1.08)	(0.77 - 1.00)	(0.77 - 1.00)	(0.80 - 1.05)	(0.70 - 0.93)	(0.72 - 0.96)
DPTH3 vaccination	0.97	1.04	1.08	0.82	0.90	0.87	0.91	1.00	0.89	0.94	0.86	0.96	1.03	0.93	0.97
	(0.86 - 1.09)	(0.92 - 1.17)	(0.95 - 1.22)	(0.72 - 0.93)	(0.79 - 1.03)	(0.76 - 1.00)	(0.79 - 1.05)	(0.86 - 1.15)	(0.76 - 1.03)	(0.81 - 1.10)	(0.73 - 1.01)	(0.81 - 1.13)	(0.87 - 1.21)	(0.78 - 1.11)	(0.81 - 1.15)
Postnatal care (48 hours)	0.92	0.99	0.99	0.80	0.72	0.72	0.76	0.83	0.71	0.75	0.49	0.76	0.93	0.89	0.85
	(0.73 - 1.14)	(0.78 - 1.24)	(0.77 - 1.26)	(0.62 - 1.02)	(0.55 - 0.92)	(0.55 - 0.94)	(0.57 - 0.99)	(0.62 - 1.10)	(0.53 - 0.94)	(0.55 - 1.01)	(0.36 - 0.67)	(0.55 - 1.04)	(0.66 - 1.28)	(0.63 - 1.24)	(0.60 - 1.20)
Postnatal care (within 3 to 7 days)	0.99	0.99	1.00	0.92	0.97	0.94	0.95	0.94	0.95	0.96	0.96	0.95	1.04	1.01	1.01
	(0.92 - 1.05)	(0.92 - 1.06)	(0.93 - 1.08)	(0.85 - 0.99)	(0.90 - 1.05)	(0.87 - 1.02)	(0.87 - 1.04)	(0.86 - 1.03)	(0.87 - 1.05)	(0.87 - 1.06)	(0.87 - 1.05)	(0.86 - 1.05)	(0.94 - 1.16)	(0.91 - 1.12)	(0.91 - 1.13)
Treatment of malaria with															
Coartem (children under 5)	1.01	0.97	1.02	0.89	0.78	0.76	0.73	0.67	0.62	0.84	0.82	0.63	0.70	0.69	0.79
	(0.72 - 1.39)	(0.68 - 1.34)	(0.70 - 1.46)	(0.60 - 1.29)	(0.52 - 1.17)	(0.49 - 1.15)	(0.47 - 1.12)	(0.42 - 1.04)	(0.38 - 0.99)	(0.51 - 1.36)	(0.49 - 1.35)	(0.37 - 1.07)	(0.37 - 1.33)	(0.38 - 1.25)	(0.44 - 1.38)
First well-child visit	1.04	1.01	1.48	0.84	1.11	0.94	1.27	1.30	1.41	1.10	2.17	0.76			
	(0.62 - 1.71)	(0.58 - 1.74)	(0.80 - 2.76)	(0.47 - 1.48)	(0.60 - 2.06)	(0.49 - 1.83)	(0.64 - 2.55)	(0.65 - 2.62)	(0.67 - 2.96)	(0.54 - 2.22)	(1.02 - 4.53)	(0.35 - 1.65)			
Family planning (new user)	0.92	0.99	0.99	0.80	0.72	0.72	0.76	0.83	0.71	0.75	0.49	0.76	0.85	0.89	0.93
	(0.73 - 1.14)	(0.78 - 1.24)	(0.77 - 1.26)	(0.62 - 1.02)	(0.55 - 0.92)	(0.55 - 0.94)	(0.57 - 0.99)	(0.62 - 1.10)	(0.53 - 0.94)	(0.55 - 1.01)	(0.36 - 0.67)	(0.55 - 1.04)	(0.60 - 1.20)	(0.63 - 1.24)	(0.66 - 1.28)

Mortality impact

Using the LiST for 2020, the number of estimated excess deaths (and relative increase) is 11,337 (12.8%) children under five, 5,705 (11.3%) neonates, and 387 (7.6%) mothers (4.6), compared to a scenario without COVID-19 (table 4.6).

Table 4.6. Mozambique's relative reduction in service counts, by indicator and month for 2020 and first quarter of 2021

	Total expected deaths in 2020 with no disruptions (counterfactual)	Total estimated deaths in 2020 with observed disruptions	Excess deaths in 2020 due to service disruptions	Relative increase in mortality due to service disruptions
Child deaths (0-59 months of age)	88,853	100,190	11,337	12.8%
Neonatal deaths (newborns <1 month of age)	50,311	56,016	5,705	11.3%
Maternal deaths	5,084	5,471	387	7.6%

Discussion

To assess the early impacts of COVID-19 on maternal and child health service provision and maternal and child mortality in Mozambique, we analysed data from the country's routine health information system between January 2020 and March 2021 and compared it with data from before the pandemic. We focused on the early stages of the pandemic when a COVID-19 vaccine was not yet available, there was limited and centralised laboratory capability to diagnose COVID-19, there was little to no clinical experience with a respiratory distress disease outbreak, and before the delta

variant emerged as the dominant strain. Moreover, during this period, the government of Mozambique instituted a state of emergency between April and August 2020, then changed to a state of public calamity in September 2020. These restrictions included police-reinforced measures to reduce movement and access to public spaces and services(5). From April 2020 through March 2021 we found evidence of substantial service provision loss in selected indicators across the maternal child health care continuum in Mozambique. These losses are estimated to have contributed to a substantial increase in maternal, neonatal, and child mortality in 2020. Our findings complement findings from a report published in April 2022 indicating an overall negative impact on health services utilisation as a result of COVID-19 from March through December 2020 in Mozambique (6). In addition, our study adds to the literature on maternal and child health service utilization losses due to COVID-19 in other sub-Saharan African countries (22,23), and will contribute to planning for Mozambique's health system recovery. To our knowledge, this is the first study on the early impacts of COVID-19 on maternal and child healthcare service utilisation and mortality conducted in one of the six African Portuguese-speaking countries.

The overall magnitude of losses in our selected indicators of maternal child health service provision are similar to what was reported for other sub-Saharan countries(23,24), except for new users of family planning and the number of children treated with Coartem, which in our analysis reached almost 30% of service count loss. The provision of these two services includes an enormous contribution of the community health workers (CHW) in rural areas. The restrictions due to emergency or public calamity state halted CHW activities, which likely contributed to the observed service disruption. It is notable that despite experiencing losses below 10% of expected service counts, other services had accelerated losses in the first quarter of 2021. These losses represent a major blow to the efforts towards universal health coverage; however, the losses could

potentially be worse still if there had not been a well designed and implemented multi-sectorial response to prevent COVID-19 transmission (5). Still, it could be argued, as well, that some of the measures may have contributed to the losses(25).

We can group the losses in our analysis in three patterns of service loss over the months of 2020 and first quarter of 2021 (table 4.5). The first includes indicators that experienced one month of loss (below 95% of the expected) or did not change over the course of the year relative to the expected. This is the case with first antenatal care visit counts, which in April 2020 were 13% below the expected. The second pattern includes those outcomes reduced to below 95% of what was expected for between two and four months. This group includes institutional deliveries and first well-child visits. The third group encompasses indicators that sustained more than four months with observed counts below 95% of what was expected. This group included immunization indicators (measles and DPTH3), post-natal visits, malaria treatment with Coartem, and family planning visits. Nevertheless, at the sub-national (province) level, there were substantial variations with Maputo City and Maputo Province showing loss of service provision (or utilization) of malaria treatment with coartem for more than 4 months, a completely different pattern to that of the other provinces. Many factors could concur with this observation. First, on the one hand, in recent years, Maputo Province and Maputo City reached a higher community prevalence of knowledge for malaria prevention and treatment that may contribute to lower malaria incidence compared to previous years. On the other hand, these two provinces were the ones with the highest reinforcement of COVID-19 prevention measures that could have contributed to deterred service utilization.

The first and second pattern of loss indicators, including first antenatal care, institutional deliveries and first well-child visits, were targeted by the National Directorate of Public Health in reaction

to earlier service count drops after April 2020. The third group of indicators include services that are sensitive to health system changes like service discontinuation to provide COVID-19 treatment or health facility closure, insufficient personal protective equipment available for health care providers, and interruptions in the supply of medical equipment and health products, which likely contributed to their prolonged decrease. Notably, family planning services were the most affected likely due their reliance on community health workers.

Although our estimates of mortality due to service provision loss (an increase of under-5 child mortality by 11% and maternal mortality by 8%) are small relative to other estimates for Mozambique(3,26), this increased mortality is concerning as it rolls back the hard-fought gains Mozambique has achieved in reducing maternal and child mortality.

Our data analysis is based on selected indicators from the Ministry of Health's RHIS combined with population size estimates at the district level. Due to high levels of missingness (above 40% of the expected observations), a small number of indicators were included in our analysis. This study supports the need for further investments in RHISs as an essential health system building block that supports health system resilience by providing timely monitoring and feedback to health system authorities, and thus are a core element of health service recovery planning (9).

During the COVID-19 pandemic new health information tools were introduced to support the response to the evolving health provision needs (27). However, these changes were largely vertically designed and implemented, and did not integrate into the routine health information system (28). Efforts to transform these vertical systems into broader RHIS improvements should be prioritized in the efforts to restore routine health services. Lessons from this experiment can help identify future opportunities, such as a digital transition of RHIS that may improve responsiveness of the health system in real-time.

Strengths and limitations

We consider the use of RHIS data at the national level over time to be a strength of this study and to provide a model for similar analyses using the RHIS for policy evaluation (29). We used RHIS data which was readily available for 24 months before the COVID-19 pandemic and for the first 15 months of COVID-19. This allowed us to estimate the expected counts for each indicator if COVID-19 didn't happen, an essential step to compare with during COVID-19 service provision counts. Although we could not include Cabo Delgado province, our data is representative of Mozambique.

Of the 11 Mozambican provinces, we could not include Cabo Delgado province because of the military insurgency affecting large areas of the province with public service unavailability, massive population migration, including health providers, and destruction of health facilities and infrastructure. This situation led to an inability to record data into RHIS and to properly assess, monitor and plan the health service provision in Cabo Delgado. This province has a damage beyond service disruption due COVID-19. For Cabo Delgado there is first need to restore peace and then a reconstruction of facilities and restoration of the health system. While the war continues efforts to restore the relief from the humanitarian crisis should be prioritized.

Our estimates are based on the assumption that the magnitude of relative reduction in health facility service utilisation represents changes experienced at the district level. While RHIS data do not include services provided through the private sector, and there could be unmeasured changes in population size due to migration patterns, we are confident that our district-level estimates are sound given the lack of observed population migration (particularly under COVID-19 restrictions) and the lack of utilization of private health facilities outside of Maputo City. Second, we cannot provide uncertainty estimates from this model.

We chose a limited number of indicators along the maternal and child health care continuum based on data completeness and history of data collection. Therefore, this dataset might not fully capture service delivery disruptions (for example, malnutrition indicators may have worsened, as was documented during the early pandemic in Eastern and South Africa(30)). In addition, our analysis was based on routine data from health facilities, which may not capture service utilisation at the community level.

Conclusions

This study provides evidence of the negative impacts of COVID-19 on selected maternal child health service provision in Mozambique during 2020 and the first quarter of 2021. In addition, it estimates the number of children and mothers who died from such service losses. In doing so, it is another example of how RHIS can be used to quickly assess and inform a health system for better action.

These findings have important implications both within Mozambique and for the larger global health community. Plans and guidance for health system recovery can rely on data generated through routine health information system which calls for efforts to be directed to prevent parallel data collection systems. Furthermore, future epidemic responses should consider the essential role that community health workers provide in the health sector (such as in the delivery of family planning and malaria treatment). At the global level, our findings contribute to documentation of service disruptions related to a significant pandemic, and provides a model of how routine health information system data can be combined with modeling tools to provide robust, granular estimates of service disruption and associated mortality.

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Abbreviations

CHW	Community Health Workers
DINAGECA	National Directorate of Geography and Cadastre (Direcção Nacional de Geografia e Cadastro)
DNSP	National Directorate of Public Health (Direcção Nacional de Saúde Pública)
LiST	Lives Saved Tool
RHIS	Routine Health Information System
SISMA	Health Information System for Monitoring and Evaluation (Sistema de Informação em Saúde para Monitoria e Avaliação)
WHO	World Health Organization

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Chapter 5: Overall Conclusions

CHAPTER 5: OVERALL CONCLUSIONS

There is a health system in Mozambique that can be strengthened by interventions designed to tackle real problems identified by actors inside the system, with synergistic collaboration of academic and other partnerships and appropriate funding. Furthermore, such a health system was able to respond and absorb shocks such as the COVID-19 pandemic, natural disaster, or war.

Mozambique PHIT partnership was designed to reduce child mortality by improving maternal and child healthcare service provision and coverage. It used management, finance, and data quality activities to influence all WHO system blocks in a large population area between 2010 and 2015. The following conclusions are most relevant as results of the Mozambique PHIT partnership:

- 1) Mortality – Mozambique PHIT did not contribute to an additional mortality reduction.

Mozambique already had a very rapid reduction in child and infant mortality, and the intervention did not change this trend.

- 2) Healthcare service utilization – Mozambique PHIT improved some health utilization coverage indicators, including the 4th antenatal care, the intermittent preventive treatment in pregnancy, and skilled birth attendance. However, no impact was observed in the child immunization.

- 3) Health service provision – The intervention was associated with improvement in antenatal care and institutional delivery. However, it did not improve the maternal HIV testing, intermittent preventive treatment in pregnancy and long-term immunization service provision.

- 4) Resilience to COVID-19 shock – Findings from our study support existing research showing the negative impact of COVID-19 on maternal and child health services utilization in sub-

Saharan Africa. This study offers subnational and granular estimates of service loss that can be useful for health system recovery planning but also how Mozambique's health system recovered fast.

This dissertation contributes to the use of routine health information system data combined with modeling tools to provide robust, granular estimates of service disruption and associated mortality.