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# Three Economic Studies on HIV in Sub-Saharan Africa

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Thesis submitted in fulfilment of the requirements for the degree  
of Doctor of Philosophy at Imperial College London

CLH

2023

## **Statement of Originality**

I hereby certify that this thesis is comprised entirely of my own original work, conducted under the kind supervision of Dr Marisa Miraldo and Dr Katharina Hauck. An earlier version of the work in Chapter 2 was presented at the World Congress on Public Health (Online, in Rome, Italy) in October 2020, and to the World Health Summit and the Berlin-Brandenburg Academy of Sciences and Humanities (BBAW) in Berlin, Germany in October 2019. As part of the World Health Summit, an earlier version of an abstract for Chapter 2 was published in the *European Journal of Public Health* in 2020 (Hansen et al., 2020). I extend my thanks to the organisers of the World Health Summit for this opportunity. Similarly, a preliminary abstract for the work in Chapter 3 was published in the *European Journal of Public Health* in October 2022 (Hansen et al., 2022). All material that is not my own has been duly acknowledged and referenced.

All errors remain my own.

**Christa Hansen**

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## **Abstract**

Since the early 1980s, HIV has been the largest adverse health shock many countries have faced to date, resulting in significant impacts on life expectancy and mortality, in tandem with major economic effects. Two-thirds of people living with HIV (PLHIV) live in Sub-Saharan Africa (SSA). As a result of significant progress made in prevention, diagnosis, and care, PLHIV now have a near-normal life expectancy. As the situation regarding HIV has improved in SSA, interventions aimed at preventing further infections, and supporting the ill, have evolved as well. Today, there is a large focus on living well with HIV, in addition to prevention and suppression programmes. In this thesis, I first investigate the economic consequences of HIV in Chapter 2. I focus on the gold mining industry, as it is an important industry in SSA, and there is a high prevalence of HIV among the mining workforce. I use a panel of 43 countries over a 28-year period and find evidence that the presence of HIV has a significant, downward impact on gold production. Next, in Chapter 3, I utilise data from a test and treat intervention, the PopART trial, and examine the impact of the trial on the distributional inequity of healthcare utilisation. I find a pro-rich inequity in healthcare utilisation, as ranked by wealth both before and even more so after the trial was implemented. “Pro-rich” implies, for example, that the 20% poorest make up less than 20% of healthcare utilisation. This suggests that the trial enabled the wealthier subset of the population to take better advantage of accessing healthcare. In Chapter 4, I continue to pursue the concept of subgroups, as I utilise the PopART data further to explore heterogeneous impacts of the trial on various health-related quality of life (HRQoL) outcomes. I study sex, wealth, and employment-type subgroups. I conclude that the trial has reduced HRQoL in certain treated populations compared to control subgroups.

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## Abbreviations

|          |                                                                                                                                                          |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| AIDS     | Acquired Immune Deficiency Syndrome                                                                                                                      |
| A-B      | Arellano-Bond                                                                                                                                            |
| ART      | Antiretroviral Treatment                                                                                                                                 |
| ARVs     | Antiretrovirals                                                                                                                                          |
| ASM      | Artisanal & Small-Scale Mining                                                                                                                           |
| ATI      | Analytical Treatment Interruptions                                                                                                                       |
| BBAW     | Berlin-Brandenburg Academy of Sciences and Humanities                                                                                                    |
| CD4      | Cluster of differentiation 4; a glycoprotein that serves as a co-receptor for the T-cell receptor                                                        |
| CD4+     | T helper cells; white blood cells essential to the human immune system: they send signals to other types of immune cells to destroy infectious particles |
| CDC      | Centers for Disease Control and Prevention                                                                                                               |
| CHiPS    | Community HIV Providers                                                                                                                                  |
| DALYs    | Disability-adjusted Life Years                                                                                                                           |
| DHS      | Demographic and Health Surveys                                                                                                                           |
| DID      | Difference in differences                                                                                                                                |
| EDC      | Electronic Data Capture                                                                                                                                  |
| EPP      | Estimation and Projection Package                                                                                                                        |
| EQ-5D-5L | Descriptive system for health-related quality of life states in adults, consisting of five dimensions, each of which has five severity levels            |
| GMM      | Generalised method of moments                                                                                                                            |
| HIC      | High-Income Country                                                                                                                                      |
| HII      | Health Inequity Index                                                                                                                                    |
| HIV      | Human Immunodeficiency Virus                                                                                                                             |
| HPTN     | HIV Prevention Trials Network                                                                                                                            |
| HRQoL    | Health-Related Quality of Life                                                                                                                           |
| HVTN     | HIV Vaccine Trials Network                                                                                                                               |
| LBMA     | London Bullion Market Association                                                                                                                        |
| LMICs    | Lower Middle-Income Countries                                                                                                                            |

## **Abbreviations cont.**

|        |                                                                                    |
|--------|------------------------------------------------------------------------------------|
| MSM    | Men Who Have Sex with Men                                                          |
| MTCT   | Mother-to-Child Transmission                                                       |
| NCDs   | Non-Communicable Diseases                                                          |
| PCA    | Principal Component Analysis                                                       |
| PLHIV  | People Living with HIV                                                             |
| PopART | Population Effects of Antiretroviral Therapy to Reduce HIV Transmission (HPTN 071) |
| RCT    | Randomised Controlled Trial                                                        |
| SES    | Socio-economic Status                                                              |
| SSA    | Sub-Saharan Africa                                                                 |
| STI    | Sexually Transmitted Infection                                                     |
| TB     | Tuberculosis                                                                       |
| UNAIDS | The Joint United Nations Programme on HIV/AIDS                                     |
| USGS   | The U.S. Geological Survey                                                         |
| UTT    | Universal Test and Treat                                                           |
| VCT    | Voluntary Counselling and Testing                                                  |
| VMMC   | Voluntary Medical Male Circumcision                                                |
| QoL    | Quality of Life                                                                    |
| WDI    | World Development Indicators                                                       |
| WHO    | World Health Organization                                                          |

# **1 Chapter 1: Introduction**

## **1.1 Clinical and Temporal Evolution of the HIV Epidemic**

### **1.1.1 Overview of the Natural History of HIV**

HIV has remained a major global scientific, social, health, and economic concern since the virus was first identified in 1981 (UNAIDS, 2008). HIV1 has been the largest adverse health shock experienced by some countries, which have endured life expectancy declines by up to two decades (Haacker, 2016).

Since the discovery of the disease, first identified by an unusual cluster of cases of *Pneumocystis carinii* pneumonia and Kaposi sarcoma in previously healthy men who have sex with men (MSM), significant advances in the understanding of HIV, and AIDS, have been made (Wood, 2018). HIV infection may be divided into three stages. The first is viral transmission – the act of spreading the infection through sexual intercourse, or through exposure to infected blood. Risk factors for transmission include, but are not limited to, risky sexual behaviours, a lack of circumcision, and needle sharing, according to Dorak et al. (2004), Gray et al. (2001), and Quinn et al. (2000). Following transmission comes the second stage, acute and early HIV infection. As treatment options have advanced, today there are options for early combination antiretroviral therapy (ART) initiation if early and acute HIV infection is identified.

ART offers viral suppression and immunological recovery. Without treatment, early HIV infection is associated with a high risk of viral transmission (Cohen et al., 2011; Wawer et al., 2005). In some cases, it has been found that up to 50% of new infections are transmitted from acutely infected individuals (Pilcher et al., 2004; Sax, 2020; Xiridou et al., 2004).

The third stage of HIV infection is chronic infection, which can include chronic infection without AIDS, which is what is seen most commonly today, thanks to immense global efforts to roll out wide-scale testing and treatment. However, when an infection is not diagnosed early, HIV infection can lead to AIDS, which is characterised by a CD4 cell count of less than 200 cells/cubic millimetre. Worse, an individual can subsequently reach the stage of advanced HIV infection, characterised by a CD4 cell count of less than 50 cells/cubic

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<sup>1</sup> Some sources throughout this thesis have made reference to “HIV/AIDS”; however, I use the term “HIV”, unless a statistic is related specifically to AIDS, defined by the Centers for Disease Control and Prevention (CDC) as a CD4 count of less than 200 cells/cubic millimetre.

millimetre (Wood, 2018). Mortality from HIV has become considerably less common due to widespread use of ART. Indeed, most HIV patients are now able to enjoy a normal life expectancy (Teeraananchai et al., 2017). However, if individuals receive a late diagnosis, or do not engage with, or adhere to, ART, death from AIDS or advanced HIV infection may occur. Typically, individuals with HIV who do not take ART will progress to AIDS over five to ten years (Wood, 2018). The median survival of patients with advanced HIV infection is 12–18 months (Easterbrook et al., 1993; Phillips et al., 1992; Teeraananchai et al., 2017).

It is difficult to directly translate impact of the relative infectiousness of an individual's choice and risk behaviour during each stage of infection, throughout that infected individual's lifetime into general population epidemic dynamics. This is due to the private nature of sexual acts that occur, which are the main modes of transmission, and differentials between sexual mixing networks and serial monogamy, among individuals who may be at different stages of HIV infection (Hollingsworth et al., 2008). It is possible to comment on general modes of transmission, and the relative risks of transmission and acquisition. Sexual transmission is known to be the most common mode of transmission globally. However, the likelihood of an individual becoming infected with HIV during sexual contact depends on many factors. For example, male to female penile-vaginal transmission is two to three times more efficacious than female to male transmission, assuming the former is the infected party in both instances (Morison, 2001).

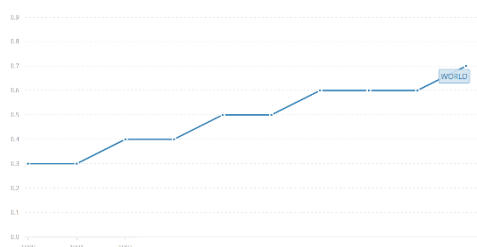
With any mode of transmission, a higher viral load of the infected party, as described when identifying the various stages, implies a higher chance of transmission. Anal intercourse has been found to be riskier than vaginal intercourse, which has obvious implications for MSM. Biological co-factors that can increase transmissibility include the presence of another sexually transmitted infection (STI), and a lack of male circumcision (Morison, 2001). Beyond sexual acts, additional modes of transmission may include parenteral transmission of HIV, generally through needle sharing, as well as through mother-to-child transmission (MTCT). In 2019, new HIV infections in children were estimated to number approximately 150,000 globally (Putta et al., 2022). Two-thirds of MTCT occurs *in utero* or at delivery, and one-third occurs during breastfeeding (Morison, 2001). Presently, 2.8 million children and adolescents aged 0–19 years are living with HIV (Putta et al., 2022).

### 1.1.2 Geographical Impacts

HIV has impacted distinct parts of the world differently. There were an estimated 37.7 million people living with HIV (PLHIV) at the end of 2020, with two-thirds of those living in Africa (WHO, 2021b). As seen in the following figures, since 1999, the global HIV prevalence has levelled off to today's prevalence rate of 0.7% (UNAIDS, 2021b; WDI, 2020). However, the prevalence remains a concern in Sub-Saharan Africa (SSA). At the peak in 2001, the prevalence in SSA was 4.7%, and by 2020, due in part to the widespread distribution of affordable ART, as well as many other initiatives, including condom use and medical male circumcision, the prevalence had dropped to 3.6% (WDI, 2020). However, interpreting prevalence rates can also be misleading, as treatment regimes such as ART have the dual effect of reducing transmission, whilst also increasing prevalence through the significantly improved lifespan expectations of PLHIV (Bor et al., 2013).

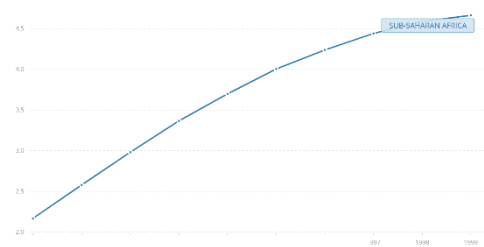
**Figure 1**

*World HIV Prevalence – 1999*



**Figure 2**

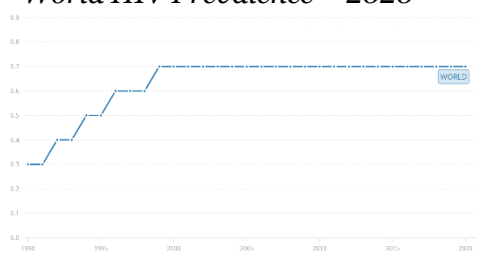
*SSA HIV Prevalence – 1999*



Source: WDI (2020)

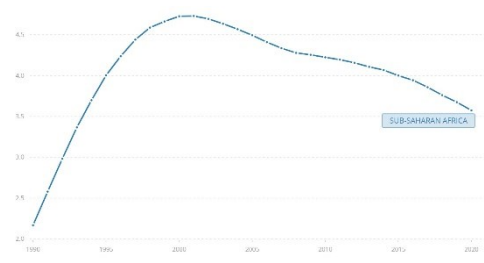
**Figure 3**

*World HIV Prevalence – 2020*



**Figure 4**

*SSA HIV Prevalence – 2020*



Source: WDI (2020)

Further, the average prevalence masks the great variation among the 46 countries defined as SSA. For example, in 2020, the prevalence rate in Botswana was 19.9%, yet in Chad it was 1.1% (WDI, 2020). In Ghana, the prevalence was 1.7%, while in South Africa it was 19.1% (WDI, 2020). In terms of disease burden, the global HIV mortality peaked in 2006 with 1.95 million deaths due to HIV. Although this figure decreased to 0.95 million deaths in 2017, HIV mortality rates still differ substantially across the globe, with 75.0% of deaths occurring in SSA in 2017 (Pandey & Galvani, 2019). Between 1990 and 2007, every country in SSA, with the exception of Uganda, Burkina Faso, and Mauritania, had a rising annualised rate of change in HIV deaths (Pandey & Galvani, 2019), until the impacts of ART and other prevention initiatives slowed these rates.

## **1.2 Impact to Date of ART Scale-up and Global Initiatives**

There have been many prevention and treatment interventions aimed at combatting HIV, the most effective of which has been ART. ART has been found to reduce mortality and transmission, as well as decreasing the number of AIDS and non-AIDS-related complications, including diabetes, hepatitis B and C, and tuberculosis (TB) (Sax, 2022). With regards to TB, not only does ART reduce the risk of developing TB in HIV patients, even though incidence rates remain higher than in the general population, but it also improves the treatment outcomes for those with TB, regardless of whether individuals are located in a resource-rich or -limited country (Gupta et al., 2012). For those individuals with low CD4 counts – under 200, for example – ART helps prevent the progression of the disease, and assists in improving any underlying co-morbid conditions. Additionally, long regimens of ART have been shown to be effective in preventing MTCT, and less complex and cheaper regimens have been demonstrated to reduce MTCT by up to half in infants who are not breastfed (Morison, 2001).

To address these health and economic challenges in recent decades, many policies have been implemented in order to control transmission and improve diagnosis and linkage to care. These have included access to ART, behavioural strategies, such as increased condom use, and official policies, including information about transmission risks and the promotion of HIV prevention methods (Hallett et al., 2006). Incredible advances have been made in the past 15 years, when the goal has been to put three million people on

ART by the end of 2005 – the “3 by 5 Initiative” (WHO, 2003). Today, there is universal access to ART, which is immediately initiated upon diagnosis, regardless of CD4 count (WHO, 2015).

To facilitate the ART rollout, in 2000, five United Nations organisations partnered with five pharmaceutical companies to offer antiretrovirals (ARVs) at 10% of the commercial price to countries in resource-poor settings. By 2006, almost half a million Africans were on ARV treatment (Van der Borgh et al., 2009). In 2017, The Global Fund to Fight AIDS, Tuberculosis and Malaria reported a 48% decline in HIV deaths since 2004, and a 50% reduction in HIV incidence (The Global Fund, 2017). One cost-benefit analysis of providing antiretroviral treatment in a large South African mining company projected financial savings of up to 17% between 2003 and 2022 (WJEC, 2022).

The achievements of the prevention and treatment interventions inspired ambitious, widely broadcasted global goals, many of which were spearheaded by the WHO and the Joint United Nations Programme on HIV/AIDS (UNAIDS), among others. The success of these many interventions has led UNAIDS to today’s pledge, outlining a range of goals with the potential for substantial public health and economic gains from a “fast-tracked” goal to end HIV as a public health threat. In May 2016, during the 69th session of the World Health Assembly, a new Global Health Sector Strategy was agreed upon for 2016–2021, where the outlined goal was to end AIDS as a public health threat by 2030, safeguarding lives and promoting well-being for all at all ages (Lazarus et al., 2016; WHO, 2016). The stated goals at the time of the announcement included, but were not limited to: reducing new adult HIV infections from 2.1 million in 2010 to 500,000 in 2020; avoiding 28 million HIV infections between 2015 and 2030; avoiding six million child infections by 2030; avoiding 21 million AIDS-related deaths between 2015 and 2030; avoiding USD 24 billion in further costs for HIV treatment; and enabling countries to gather a 15x return on any HIV investments (WHO, 2016).

A recent UNAIDS panel, “Addressing Inequalities to End AIDS: 10 Years to 2030” (UNAIDS, 2021a), suggested the following: HIV is fuelled by inequalities. All panellists emphasised the need for transformation to end social, economic, racial, and gender barriers, including stigma and discrimination based on HIV status (UNAIDS, 2021d). This panel supported the academic literature on inequalities and HIV. Much of the literature ties together concerns over quality of life and inequalities. Nigusso and

Mavhandu-Mudzusi (2021) present evidence on the link between health-related quality of life (HRQoL) and “social inequalities”. The authors find, especially for PLHIV in SSA, that the magnitude of social inequalities is quite severe and largely contributes to the detriment of quality of life in terms of unemployment and food security (Nigusso & Mavhandu-Mudzusi, 2021).

Many global targets have been set for HIV as health for PLHIV has improved, all of which go beyond the existing end point of viral suppression (UNAIDS, 2014; WHO, 2016). Recent HIV targets include: (1) the reduction of HIV-related deaths, including those with co-morbidities such as TB and hepatitis B and C; (2) testing and treatment, which the UNAIDS 90-90-90 goals fall under, for 90% of those living with HIV to know their status, for 90% of those diagnoses to be receiving antiretroviral treatment, and for 90% of those living with HIV to achieve viral load suppression; (3) prevention, keeping HIV infections below 500,000 and having zero new infant infections; (4) discrimination, ensuring that 90% of those living with HIV report no discrimination in the health sector; (5) financial sustainability, guaranteeing financial risk protection for 90% of all people living with HIV, and ensuring that countries have integrated HIV services and health financing arrangements; and lastly (6), innovation, which includes increasing the research and development of HIV-related vaccines and medicines for use in treatment and prevention (WHO, 2016).

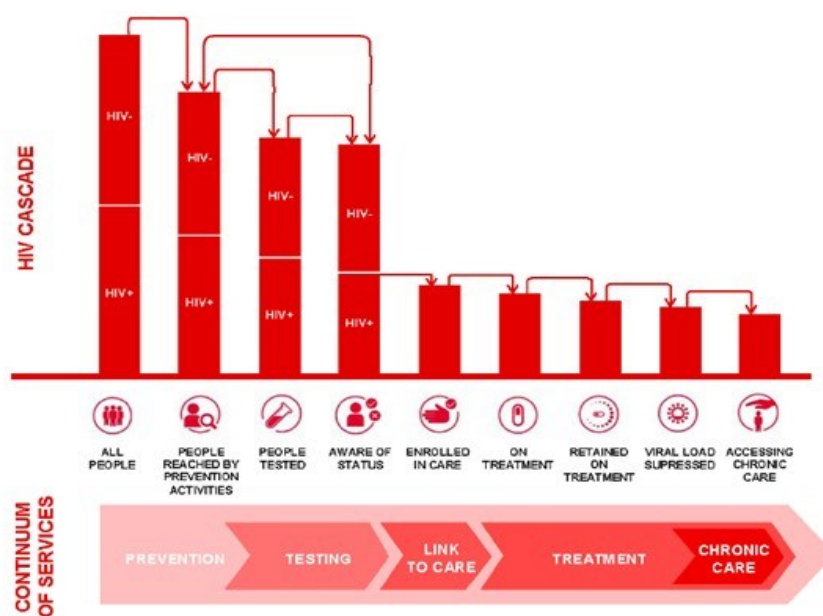
Unfortunately, we have fallen short of the original three 90-90-90 goals of PLHIV knowing their status, receiving treatment, and living virally suppressed by the end of 2020. According to a press release published on September 21, 2020, 81% of PLHIV knew their status, with a shortfall of 3.3 million individuals reaching the 90% goal, while 67% were on ART, with a shortfall of 5.4 million individuals reaching the goal, and 59% were living virally suppressed (UNAIDS, 2020; WHO, 2022). However, over the last 40 years, due to the great efforts described in terms of prevention, diagnosis, and care, we have seen a dramatic disease trajectory, from when the disease was originally a diagnosis of mortality to now, where it has transitioned into a chronic disease (Basavaraj et al., 2010; Kharsany & Karim, 2016). Looking at Figure 5, on the following page, we are in the fortunate position to be nearing the end of the right-hand spectrum in terms of care focus in most geographic areas.

This shift has changed the nature of the policies and interventions proposed by governments and international organisations. While initially global interventions

targeted viral suppression, providing universal access to treatment and care, policymakers are now more forward-looking in their focus as HIV has become a chronic disease (Haacker, 2016).

Suppression and prevention remain of primary importance. However, with the increased prevalence of PLHIV that are living longer, more needs to be done to improve quality of life (QoL) and reduce inequalities (Lazarus et al., 2016). Lazarus et al. (2016) were the first to call for a new goal, the “fourth UNAIDS 90”. The fourth UNAIDS 90 would ensure a good health-related quality of life for PLHIV. Specifically, HRQoL would encompass an individual’s self-perceived quality of life, or any co-morbidities they may have. Although the motion was ultimately dismissed as an official UNAIDS policy goal, the concept has remained popularised for valid reasons.

**Figure 5**  
*Timeline of Interventions*



Source: WHO (2016)

Many people on ART are living to be in their fifties, sixties, and beyond. HIV-related mortality is falling significantly. In 2020, 680,000 people died from AIDS-related illnesses, which was a 64% reduction since the peak in 2004, and a 47% reduction since 2010 (UNAIDS, 2021c). However, despite this improved life expectancy, there are still impacts on QoL for PLHIV. Often PLHIV live longer but with multiple co-morbidities that hamper their quality of life (Costagliola, 2014; Kooij et al., 2016; Schouten et al., 2014, 2016). As well as experiencing multiple co-morbidities, these individuals commonly suffer from mental health problems and often require pain management (Lazarus et al., 2016). Additionally, a very important factor facing PLHIV is stigma and discrimination, which can most severely impact anxiety and depression, and may also impact treatment adherence and consequently QoL (Scofield & Moseholm, 2022). Policies focused on well-being must consider how to reduce these negative factors (WHO, 2016).

The need to improve HRQoL is particularly relevant for SSA given the prevalence of HIV in the region, combined with an ageing population and ubiquitous inequalities. The population share of elderly people (60 and older) is projected to grow from 43 million to 644 million by the end of the century (Aboderin, 2012; UNDP, 2012).

### **1.3 Existing Literature on the Economics of HIV**

In addition to significant health impacts, the HIV epidemic also has severe negative impacts on the economy, as has been demonstrated in the literature. Unique in comparison to other infectious diseases, HIV is most prevalent in young and middle-aged adults during their most productive working years (Simon et al., 2000). All companies with employees who are infected with HIV, regardless of their size, suffer the indirect costs of lower productivity due to presenteeism and absenteeism, according to Habyarimana et al. (2010), Matangi (2006), Murray et al. (2005), and Simon et al. (2000). In Zambia, in 1992, an estimated 31.8% of country-wide HIV-related costs were due to absenteeism; in Kenya, in 1994, the estimate was 54.3%; and in Zimbabwe between 1995 and 1996 the burden was 25.2%, according to Loewenson and Whiteside (1997) and Hayman et al. (1996). Thus HIV effects on the labour force inflate costs in the economy at large.

Before the widespread intervention of ART, business costs in Africa as a result of HIV were significant and rapidly increasing. Hayman et al. (1996) found that in Kenya, between 1992 and 2005, the costs of HIV per employee in USD in the sugar industry rose by 203%. Similarly, the wood processing industry saw a rise in costs per employee of 189%. The transportation industry saw a rise of 144%, and costs in heavy industries, which include mining and manufacturing, rose by 137% (Hayman et al., 1996). These differences in costs are thought to be attributable to differences in the way HIV-infected employees were treated. For example, some companies were found to provide employees with on-estate housing, as well as medical care. Additionally, there are the more traditional productivity losses due to absenteeism, AIDS-related deaths, and increases in medical costs (United Nations, 2004b).

In response, larger companies often paid the direct costs for the treatment of sick employees, as well as the larger costs of health and insurance benefits. As these costs began to impact businesses at too great a level, companies tried to shift the cost of the epidemic onto the public sector, sometimes by reducing privately offered health services, so that individuals were forced to turn to the public sector. When the burden on the public sector becomes too great, it has often been shifted back to individuals and households (Barks-Ruggles et al., 2001). These economic losses reflect more widely on growth and the economy. The reduction in GDP in Africa caused by the HIV endemic has been estimated to be in the range of 2–4 % per year (over the period 1960–1998) (Dixon et al., 2001), with large variations across countries in line with the prevalence of HIV.

Equity is an important metric of health systems (O'Donnell et al., 2007). Assessing inequity in healthcare provides great value in terms of policymaking. Measuring horizontal inequity qualifies inequalities within a framework of fairness, enabling us to assess the extent to which unequal distributions are validated, as perhaps they reflect different health needs (O'Donnell et al., 2007). Most of the existing inequities research on healthcare utilisation is in child and maternal health in SSA (Nghargbu & Olaniyan, 2017). An additional work by Yuan et al. (2014) examines in a systematic review which of 22 interventions on maternal and child health were more effective in reducing equity.

Although PLHIV now have a near-normal life expectancy (Kharsany & Karim, 2016),

in lower middle-income countries (LMICs), specifically in SSA, people are still suffering due to a lack of diagnoses and linkage to care, and late initiation of treatment (Hansoti et al., 2017). Universal testing and treatment trials provide early diagnosis and an immediate linkage to care, both of which may impact quality of life, with the direction of impact not immediately obvious (Hayes et al., 2014). Kagee and Martin (2010), Olley et al. (2004), and Reynolds et al. (2009) have demonstrated that, in the short term, an individual's HRQoL may drop, particularly in relation to self-care, anxiety, or depression. This may be related to the process of internally processing a new diagnosis or sharing a diagnosis with others. Similarly, Cooper et al. (2017) and Drewes et al. (2013) found decreases in HRQoL related to relationships, including family and friends.

However, in contrast, by improving access to treatment, population health is improved as new infections are prevented and better care provided. A higher HRQoL is found from the subsequent extended life expectancy and improved health, specifically through decreased pain (Jelsma et al., 2005; Robberstad & Olsen, 2010), and the increased ability to carry out daily activities (Peltzer & Phaswana-Mafuya, 2008).

#### **1.4 Thesis Aims and Research Questions**

In this thesis I investigate three specific research questions on the economics of HIV. These research questions are driven by specific gaps in the existing literature base. First, I investigate the impact of HIV on economic activity, specifically examining the impact of HIV prevalence on the gold mining industry. This research is driven by a lack of existing research on the impact of HIV on economic activity at the macroeconomic level. The majority of the present literature base is focused on productivity losses at the firm level. An additional unique aspect of my research is the estimation of causal economic impacts through the use of the Arellano-Bond methodology, which takes into account any reverse causal effects. My work provides a novel, unique contribution to the field of HIV, economic outcomes, and productivity loss across SSA.

My second research question focuses on the impact of an HIV treatment and prevention trial, HPTN 071 (PopART), on the distributional inequity of healthcare utilisation in Zambia and South Africa. PopART is the largest randomised controlled trial (RCT) of universal HIV prevention, testing, and treatment, with the primary aim being to reduce community-level

HIV incidence. Universal test and treat (UTT) interventions were one set of interventions developed to combat the detrimental effects of the HIV endemic. This is the first work to assess the impact of a randomised controlled trial on horizontal inequity in healthcare utilisation. The literature base has shown that the trial could have affected lower or higher socio-economic groups differently, thus impacting on horizontal equity in primary healthcare utilisation. Although there is no explicitly stated aim to reduce inequality or inequity, the trial could have impacted lower or higher socio-economic groups differently, thus impacting horizontal equity in primary healthcare utilisation.

Thus, in Chapter 3, I assess the impact of the HIV Prevention Trials Network (HPTN) 071 combination prevention (PopART) trial in Zambia and South Africa on healthcare utilisation. In this chapter, I assess the impact of PopART on the horizontal inequity in healthcare utilisation. Finally, in my third research question, in Chapter 4, I assess the impact of the trial on health-related quality of life in Zambia and South Africa, and capture the extent to which it varies across individuals, by sex, wealth, education, and employment status. It is likely that any effects of the trial will change across these varying population subgroups. This could then lead to inequality in treatment or health outcomes, which would ultimately impact HRQoL.

## **1.5 Corresponding Chapters**

The remainder of this thesis is laid out as follows. Chapter 2 presents the introduction, literature review, methodology, data, results, and a discussion of the findings on the impact of HIV prevalence in the gold mining industry. Chapter 3 follows the same format, looking at the distributional imbalances of the healthcare utilisation of Zambia and South Africa in the PopART trial. Chapter 4 studies the heterogeneous impact of the PopART trial on HRQoL. Finally, in Chapter 5, I offer concluding remarks, and a set of appendices follows, which includes minor additional support for all of the chapters.

## **2 Chapter 2: Is the Road to Good Health Paved in Gold? HIV and Mining in Sub-Saharan Africa**

### **2.1 Introduction**

The presence of HIV has long posed significant challenges to the health of the population in Sub-Saharan Africa. The latest HIV estimates in 2019 place the prevalence of HIV in SSA at 3.7%, a level far above the world prevalence rate of 0.7% (WDI, 2019). However, looking at such macroeconomic statistics can be misleading. For example, in 2019, the HIV prevalence rate in South Africa, the second-largest SSA country by GDP, soared to 19% in comparison (WDI, 2019). In 2015, UNAIDS updated guidelines for ART initiation, offering immediate initiation of care upon diagnosis (Hayes et al., 2019). Although this improved access to treatment is expected to greatly improve life expectancy (Marcus et al., 2016) and quality of life (Lifson et al., 2017; Thomas et al., 2017), HIV still has significant macro- and microeconomic impacts.

This chapter focuses on the impact of HIV on economic activity – specifically, the impact of HIV prevalence on gold production in Sub-Saharan Africa. Gold is very important for the global economy, as there is a 3.23 billion-tonne global gold market (LBMA, 2019). Gold mining is of particular importance to SSA, as 20% of the world's gold is extracted from 34 African countries (Elbra, 2014). Also, it is estimated that artisanal and small-scale mining (ASM) accounts for an additional 20% of the global gold supply (IGF, 2017). ASM is often illegal, and thus reporting is considered to be inaccurate and inconsistent (Hilson & Hu, 2022).

There are multiple channels through which HIV may impact national economies, namely macroeconomic, household, and fiscal channels. This is as per Bonnel et al. (2000), Haacker (2004), and Jefferis et al. (2008), all of whom provide motivation for this chapter. Jefferis et al. (2008) note that although less obvious than macroeconomic effects, if HIV lowers economic growth, then welfare losses may extend beyond the household level of infected individuals only. This may impact per capita incomes and, whilst having predictable detrimental effects on productivity, may have indeterminate effects on unemployment. This is discussed further in the Background and Related Literature section. Examining the impact of HIV on key macroeconomic variables, including GDP, income,

employment, and wages, we can see that HIV may impact productivity both through high morbidity, as more time is spent off work, or through poorer performance at work, and also through rising mortality, as the size of the labour force is decreased, according to Habyarimana et al. (2010), Matangi (2006), Rajaraman et al. (2006), and Sonnenberg et al. (2011). At the household level, the impact of HIV is likely to be quite variable, depending on whether a household contains an HIV-infected individual. If an HIV-positive member is present, additional expenditures on healthcare, or on funerals, might be needed. However, if a household is free of HIV, it is possible that they may actually benefit from improved opportunities if labour markets tighten (Jefferis et al., 2008). On the fiscal level, nationally, the cost of treatment and government spending is likely to be quite variable depending on what other treatment options and programmes are available. It is difficult to drill into exact impacts, which is why this chapter has taken a narrow focus, examining one specific industry, namely gold mining.

HIV is highly prevalent in the gold mining workforce (Campbell, 2000; Clift et al., 2003; Siu et al., 2012). Some mining companies have reported that up to 30% of their working population is infected with HIV (AngloGold Ashanti, 2007). Elevated prevalence rates of HIV in the mining industry are due to a variety of factors. Understanding individual attitudes towards risk is often used as a predictor to comprehend individual behaviour (Dohmen et al., 2011). Bonin et al. (2007) show that individuals willing to take risks can lead to occupational sorting. Mining is a very dangerous job, thus it is possible that individuals in the mining industry have a higher threshold for risk, and this may further increase the willingness to participate in risky factors outside of the job (WGC, 2013). Additionally, many migrant workers must travel to their jobs, often across country boundaries. The farther individuals travel to their place of occupation, the more opportunities for human contact and the potential spread of disease are created (Oster, 2012). As miners are displaced from their families, they are more likely to engage in risky behaviour, such as casual and commercial sexual relationships (Baltazar et al., 2015; Barwise et al., 2013; Corno & De Walque, 2012; Gebrekristos et al., 2005; Klein et al., 2015).

There is another key factor at work, as HIV prevalence and the associated susceptibility to other diseases (e.g. TB) is likely to impact the mining sector (Stuckler et al., 2011). This introduces a reverse causality into the relationship between HIV and mining production. The

existing literature indicates that HIV prevalence substantially impacts the mining industry through the following channels: firstly, through increased employment costs and decreased productivity due to absenteeism and presenteeism, which includes attendance at work, but performing at a reduced level, ultimately impacting profitability (Habyarimana et al., 2010; Larson et al., 2008, 2009; Matangi, 2006; Murray et al., 2005). Significant productive days are lost not only due to absenteeism and presenteeism, but also to illness, turnover, and accessing healthcare, all of which limit the available healthy workforce (IFC, 2004). Additionally, due to the productivity impacts of HIV in the mining business, many companies take on the financial burden of providing ART directly in the workplace to counter these losses in productivity and provide support to their workforce (Meyer-Rath et al., 2015). In 2002, Anglo American, the third-largest mining company in the world, became the first major company to offer free ART to its 80,000-person workforce (Rajak, 2010).

Using a difference-in-differences design with repeated cross-sectional data from around 39 newly opened mine sites in 16 different countries in SSA, in recent literature, Dietler et al. (2022) find that opening a mine increases the odds of HIV infection almost twofold. Therefore, understanding the impacts of HIV on the mining industry is of key economic importance.

If the true measure of potential economic loss is understood, policymakers may be able to put in place policies that incentivise healthy behaviours, as well as mitigating the health and economic impacts of HIV in the mining industry workforce. In this chapter, I measure the impact of HIV prevalence on gold production in Sub-Saharan Africa. As such, I contribute to the literature in the following significant ways. First, most of the literature has focused on estimating firm-specific productivity losses due to HIV. To the best of my knowledge, no paper has quantified the causal impact of HIV on economic production at the macroeconomic level, measured here in the gold mining sector, at country level in SSA. Second, while some contributions have assessed the correlation between HIV and economic losses, these contributions fail to account for the endogeneity between HIV prevalence and gold mining production. Identifying the causal impact of HIV on mining production is challenging as there is a reverse causality in the relationship, as addressed above. Miners are more likely to contract HIV, and the mining industry is very susceptible to the impacts of HIV. The industry has already implemented treatment responses to these challenges. To address this relationship, I employ an Arellano-Bond (A-B) estimation to evaluate the effects of HIV prevalence on gold

mining output in SSA. I also leverage a rich panel data set of 43 countries, spanning 28 years, from 1990 to 2017. This data set is formed from four key sources: *The U.S. Geological Survey Minerals Yearbook*, the World Development Indicators, the Polity IV Project, and the World Bank Migration and Remittances Data, all of which are compiled annually and continually updated for accuracy.

Results show that HIV prevalence is associated with a decrease in gold production, with a 1% increase in HIV prevalence resulting in an average annual production loss of 2.915 tonnes of gold, across all countries included in the sample, significant at the 10% level, valued at approximately \$118 million based on the average London Bullion Market Association (LBMA) gold price in 2017 (LBMA, 2018). This is equivalent to an approximate 7% average annual decrease in mean GDP per capita across countries in the sample (WDI, 2017). This is a meaningful finding on the magnitude of the effect of the damage that HIV has had on the industry over such a lengthy time period.

The remainder of this chapter proceeds as follows: Section 2.2 discusses the Background and Related Literature, Section 2.3 outlines the Data Sources, Section 2.4 describes the Methodology, Section 2.5 details Results, and Section 2.6 concludes with a Discussion.

## **2.2 Background and Related Literature**

Poor health impacts a wide variety of economic outcomes (Weil, 2007). Health may be viewed as both a consumption and investment good, where individuals invest in their health, and better health generates more productivity. This is the concept of “health as human capital” (Grossman, 1972). Strauss and Thomas (1998) focus on investment in health to promote labour market outcomes. This is evidenced by health as human capital strengthening incentives for skill acquisition, making it more likely for an individual to undertake job training (Becker, 1964; Ben-Porath, 1967; Oster et al., 2013).

Focusing specifically on the macroeconomic level, health as human capital is most generally evaluated in terms of the impact of life expectancy on growth. Barro et al. (1996) find a positive, significant effect of life expectancy on economic growth in examining approximately 100 countries, observed from 1965 to 1975, 1975 to 1985, and 1985 to 1990. This confirms the earlier works of Barro and Lee (1994), Barro and Sala-i-Martin (1995), and Bloom et al. (2004), which similarly find positive, significant effects of life expectancy on economic growth. Swift (2011) and Acemoglu and Johnson (2007) measure the positive impacts of life expectancy on growth, specifically in terms of GDP and GDP per capita, respectively, which supports this body of work.

The above literature states that a longer life expectancy supports economic growth. In tandem with that, there is a body of macroeconomic literature suggesting that a reduced life expectancy limits investments in long-term preventative health behaviours, a channel that ultimately impacts growth (Dow et al., 1999; Grossman, 1972; Oster et al., 2013). These broader macroeconomic studies support the productivity literature in LMICs.

In the context of LMICs, HIV is very important when considering ill health. In 2019, HIV and other infectious diseases remained in the top 10 morbidities in low-income countries (WHO, 2021a). Health has an economic impact through two channels, as evidenced by the LMIC literature: there are direct impacts on productivity due to absenteeism and presenteeism, and also through firm-level investment in HIV prevention and treatment (Fox et al., 2004; Guinness et al., 2003; Habyarimana et al., 2010; Matangi, 2006; Murray et al., 2005; Rajaraman et al., 2006; Rosen et al., 2004; Sonnenberg et al., 2011).

There is a large body of literature indicating that HIV impacts negatively on productivity.

Due to improvements in treatment and prevention, the prevalence of HIV has declined, thus the burden of productivity has decreased over time (WJEC, 2022). Focusing on firm-level research before the ART rollout, Rosen et al. (2004) examine the cost of HIV to businesses in South Africa and Botswana. The authors draw data from six firms, including two mining companies, and estimate the economic impact on firms of sick leave, productivity losses, death, and the recruitment and training of replacement workers. The prevalence of HIV in the workforce of the studied firms ranges from 7.9% to 25.0%. Data is collected over the period 1999–2001. The authors find that the present value of an HIV infection ranges from 0.5 to 3.6 times the infected worker's salary. This cost includes direct costs of retirement benefits, death and disability benefits, and the cost of providing medical care (Rosen et al., 2004).

In addition to the direct costs to the firm mentioned above, supplemental costs to the firm may include funeral expenses for lost workers, and time off granted to current workers for attending funerals (IFC, 2004). Matangi (2006) notes that one mine manager reported granting time off to various workers to attend ten funerals in a single week. If a worker is lost from the workforce due to AIDS and eventual death, the company then incurs additional training expenses and recruitment costs to replace the worker. Before widespread antiretroviral treatment, Matangi (2006) finds these recruitment costs to be \$660 per person in Zimbabwean mining sites. The average training time for new recruits is five months, with some instances noted where an individual's training took up to a year to complete. Eleven out of 27 mining sites in the study were found to overtrain, making it difficult to appropriately match the skills of replacement workers with new jobs, thus generating unnecessary expenses as part of the recruitment cost (Matangi, 2006).

One large-scale mining company, Anglo American, has invested a substantial amount in HIV treatment in its working population. In its 2018 year-end report, the company reported major changes in recent years, with company-provided ART coverage increasing for PLHIV from 53% in 2014 to 86% in 2018 (Anglo American plc, 2018). In addition to direct treatment expenses for the firm, Anglo American also launched extensive corporate HIV prevention plans, including peer education, condom distribution, STI treatments, and voluntary counselling and testing (VCT) (Rajak, 2010). In Zimbabwe, Matangi (2006) finds the cost of running HIV programmes to be over \$1,335 a month per site at 15 mining sites.

In addition to these outright costs, stigma and discrimination in the workplace may prevent the uptake of prevention and treatment programmes (IFC, 2004; ILO, 2013), thereby reducing efficacy and productivity. Stigma and discrimination may further cause damage by reducing workplace morale.

Next, I focus on productivity losses caused by absenteeism and presenteeism in workers infected with HIV. There can be a high level of absenteeism among workers infected with HIV, as workers are unable to attend the workplace due to illness or medical appointments. Prior to the ART rollout, Fox et al. (2004), and Guinness et al. (2003) examine sick leave and absenteeism. Fox et al. (2004) study the impact of HIV on tea pluckers in Kenya between 1997 and 2002. The authors find that between 9.2 and 11.0 more sick leave days were taken and that between 11.8 and 19.9 casual leave days were taken in comparison to healthy workers. Guinness et al. (2003) find a similar impact on a panel of seven firms, including manufacturing and transport, farming and processing, food and beverage, and financial firms, between 1999 and 2001. The authors find that in the last 12 months among the workforce, the proportion of granted sick leave was 1.3% to 20.0% higher in workers infected with HIV, and absenteeism ranged from 10% to 78%. In a similar study, Murray et al. (2005), using data on miners infected with HIV in South Africa for the period 1991–2002, find that workers infected with HIV took an average of 18 additional sick days in the final year of their life.

In the gold mining industry, Sonnenberg et al. (2011) evaluate 6,562 workers, 1,703 of whom were infected with HIV, over the period 1992–2002, pre-ART initiation, in four gold mines in South Africa, finding that three excess sick days were taken per three-month period, and 18 excess days were taken in the final year of life. In the diamond mining industry in Botswana, Habyarimana et al. (2010) estimate the impact of HIV on mining absenteeism over the period leading up to, and including, the ART rollout, using a sample set of 7,661 workers over the period 1998–2006. The authors compare sickness days between PLHIV before and after antiretroviral treatment and find that an average of five excess sick days were taken by employees infected with HIV, pre-ART initiation, over a three-month period. Examining similar not industry-specific outcomes in the post-rollout era, Thomas et al. (2019) assess data from the recent PopART study in Zambia and South Africa from 2013 to 2015, a general sample where a person living with HIV may have been at any stage of the disease, and

demonstrate continued evidence of absenteeism in Sub-Saharan Africa during this period. Thomas et al. (2019) find that PLHIV lost 1.7 days over three months on average.

There is also evidence of presenteeism in gold mining. Presenteeism refers to the lost productivity that may occur when employees are not fully functioning in the workplace because of an illness, injury, or other condition. Murray et al. (2005) examine work injury rates from 1991 to 2002 in gold miners infected with HIV in South Africa. The authors find that the number of presenteeism-related work injuries was higher in workers infected with HIV, with an adjusted rate ratio of 1.3, a relative difference measure between individuals infected with HIV and those who are not. Additionally, on-the-job skills may decline as worker roles are reassigned in order to accommodate HIV-induced illness and absence. Matangi (2006) finds that HIV depresses labour productivity through gradual labour turnover resulting from morbidity and declining firm-specific skills, most notably in 36.8% of general workers. Miners are considered to be the most productive members of a country-wide body of workers. Mining production workers typically have long-term employment, and these labourers are difficult to replace as tacit knowledge and skills have been accumulated over their working life. The utilisation of existing workers in response to the challenges caused by HIV among the workforce includes job rotation, which may misalign workers' skills with the job to which they are assigned (Matangi, 2006).

The research discussed has focused on macroeconomic studies of life expectancy and growth, and microeconomic research on the individual-level impact on firms. My research goes beyond firm-level impacts in order to understand the macroeconomic effects of HIV on the total SSA mining industry. Specifically, I add to the literature in three significant ways: (a) my research focuses on a high-risk population, providing specific HIV-focused impacts on productivity. The highest HIV prevalence in the panel is 26.3%, highlighting the detrimental health impacts of this population; (b) as mentioned above, there is a reverse causality that must be considered in the estimation of any HIV impacts on gold production. Productivity is affected by higher rates of absenteeism and presenteeism in workers infected with HIV. Also, the mining industry responds to these productivity losses with investments in HIV prevention and treatment. In response to this, I implement Arellano-Bond estimation, a sound methodology that takes into account reverse causality, allowing causal estimates to be drawn; (c) my research makes use of an extensive 28-year country-level panel, and I conduct my

analysis looking at 43 countries in Sub-Saharan Africa, drawing from four different sources (Marshall et al., 2016; USGS, 2017; WDI, 2017; World Bank, 2017). This provides a comprehensive study of all countries in SSA directly or indirectly impacted by the economics of the mining industry.

## **2.3 Data**

### **2.3.1 Key Variables**

This analysis examines panel data on 43 countries in Sub-Saharan Africa over the period 1990–2017, drawing from four different sources, providing a total observation count of 693 used in the sample.

The two primary variables are the dependent variable, gold production, and the key independent variable of interest, HIV prevalence. Gold production data is measured in tonnes of gold content, and data is provided by *The U.S. Geological Survey (USGS) Minerals Yearbook* (USGS, 2017). The USGS provides information and statistics on the global supply and demand of key minerals and materials, including gold. Sourced from the USGS, the outcome variable is annual country-level gold (“*Gold*”) production. *The USGS Minerals Yearbook* statistics on world mineral production are compiled annually on approximately 90 commodities. The USGS includes annual gold production data specifically on Sub-Saharan Africa.

The independent variable of interest is HIV prevalence (“*HIV*”), are UNAIDS estimates, and were accessed through the World Development Indicators (WDI) data site (WDI, 2017). Prevalence is a measure of PLHIV in a country-level population aged 15–49. The age range of 15–49 covers the population recommended by the WHO/UNAIDS HIV/STI surveillance working group for testing strategies, as normally prevalence is higher for this range than for those who are younger or older (WHO, 2006). The WDI is a World Bank, cross-country, comparable data set compiled for the purpose of advancing country development (WDI, 2017).

### **2.3.2 Covariates**

The covariates in the analysis have been chosen based on evidence from the literature on drivers of sectoral productivity. In approaching this task, I prepared an exhaustive review of key papers on HIV and mining, mining determinants, FDI and mining, exports and productivity, and determinants of general economic productivity. Based on this review, the following covariates, explained herewith, are important controls found to be key determinants of production. Omitting these variables would lead to either biased or imprecise estimates.

Economic controls, political factors, and human capital controls are included as key macroeconomic determinants. Economic variables have been taken from the WDI. Political factor variables have been taken from the Polity IV Project (Marshall et al. 2016). The Polity IV Project is a quantitative compilation of authority characteristics of global states. Migration data is provided by the World Bank Migration and Remittances Data (World Bank, 2017). Comprehensive variable descriptions, sources, and units of measure for all variables discussed in this section may be found in Tables 1–3.

### **2.3.2.1 Economic Controls**

A range of economic controls are included as they have been found to be predictors of economic productivity. These include consumption expenditure (Arrow & Kruz, 2013; Devarajan et al., 1996), the openness of the economy (Barro, 1991; Mankiw et al., 1992; Miller & Upadhyay, 2000), country size (Helpman, 1987; Stack, 2009), infrastructure (Aker & Mbiti, 2010; Bates, 2004; Jedwab & Moradi, 2016), and GDP per capita (Barro, 1991; Jalles & Tavares, 2015; Mankiw et al., 1992; Miller & Upadhyay, 2000).

Consumption expenditure has long been a subject of focus in terms of economic growth and productivity. Many seminal pieces of literature have worked to capture the relationship between private consumption and public expenditure. Traditional theory suggests a positive relationship between expenditure and economic productivity (Arrow & Kruz, 2013), and most current research suggests there may be certain elements, such as health, for example, that may drive such a relationship (Devarajan et al., 1996). Therefore, I utilise the variable “*Consumption*”, which measures private and general government consumption as a percentage of GDP.

I also control for economic openness by building the variable “*Open*”, which measures the intensity of trade with the sum of imports and exports, as a percentage of GDP. A large, active trading market is critical for mining, as gold is an exportation product. Thus a larger degree of openness suggests an increase in mining production. This is supported by literature that finds that trade openness increases economic productivity (Barro, 1991; Mankiw et al., 1992; Miller & Upadhyay, 2000).

Country size (“*Countrysize*”), measured by land area in square kilometres, is a key variable in examining bilateral trade, as the distance between countries may be an

estimate of a hindrance to trade. This has been used especially in the gravity trade literature, which demonstrates that bilateral trade may be estimated by country size and the distance between the two countries, as countries that are more economically distant have greater trade costs (Helpman, 1987; Stack, 2009).

Increased infrastructure may be expected to translate into greater gold production, as information about labour and product supply and demand is easily transmitted. Telephone infrastructure (“*Telinfrastructure*”) is used as an indicator for infrastructure more broadly, as well as a measure of cross-country communication. Telephone infrastructure is a commonly used proxy for the general ease of doing business, and an indicator of labour productivity. With regard to infrastructure, specifically in this case, the variable *Telinfrastructure* measures telephone communications by quantifying installed infrastructure. It is unlikely that an HIV burden would impact communications infrastructure. Evidence suggests that the effects of HIV on infrastructure are through workforce effects rather than through installed physical infrastructure (for example, through reduced productivity, increased employment costs, decreased skills, or employment replacement costs). These occur in sectors where the labour workforce is more at risk of contracting HIV (e.g. transport industry) (Wamboye et al., 2016). Thus, it is unlikely that HIV burden impacts production through the installed capacity channel, which is what I control for.

Finally, I also control for GDP per capita (“*Gdpcap*”), inflation-adjusted to “real” \$US millions, measured in 2003 dollars, chosen as a midpoint of the sample. The literature indicates that higher levels of initial GDP may hinder economic productivity (Barro, 1991; Mankiw et al., 1992; Miller & Upadhyay, 2000). Specifically in regard to mining investments, Jalles and Tavares (2015) suggest there is a positive relationship between GDP and foreign direct investment.

### **2.3.2.2 Political Factors**

To control for political factors that may impact economic productivity I have included two variables, “*Democracy*” and “*Autocracy*”. These variables have been included to measure political factors such as governance and political stability (Bates, 2004). Democracy, governance, and political stability have been found to correlate with overall

economic productivity and mining, albeit with no consensus on the direction of impact. Bates (2004) finds that political instability does not necessarily slow economic growth in Africa. Competing political organisations may work hard to generate economic activity in order to direct revenue flows to support their organisation (Bates, 2004). Buccirossi et al. (2013) note that institutions, enforcement, rule of law, the legal system, market regulation, and welfare state limitations are factors contributing positively to productivity growth and competitive environments in OECD countries. However, it is possible that in low-income countries these factors may not have the same effects. Galdon-Sanchez and Schmitz (2002) find that deregulation, privatisation, and tariff reductions (increasing competition) do not increase mining productivity, specifically in the case of iron ore. Furthermore, corruption could be an important covariate as conflict leads to displacement (Black et al., 2011; Reuveny, 2007; Ruysen & Rayp, 2014). This may cause difficulties in monitoring individuals, so they may not be treated through the monitoring of HIV care. This could skew data by underestimating PLHIV. Direct data on conflict are unavailable for the duration of this panel. However, both *Democracy* and *Autocracy* capture any periods of central authority interruption, collapse, or transition, and thus act as a proxy for corruption and conflict.

### **2.3.2.3 Human Capital**

Human capital is captured in schooling, unemployment, and migration. Thus, I have created the indicators “*Primary School*”, “*Unemployment*” (Barro, 1991; Buccirossi et al., 2013; Jalles & Tavares, 2015; Mankiw et al., 1992; Miller & Upadhyay, 2000), and migration, “*Migcap*” (Bazzi et al., 2016; Lucas, 1987; Peri, 2012). Educational achievement and unemployment, as indicators of human capital, are expected to have positive and negative effects on mining output, respectively. Therefore, I build a proxy for education level, “*Primary School*”, which measures the total enrolment, regardless of age, in primary school. One note with regard to education: it is indeed plausible that HIV impacts education enrolment (Njelesani, 2011; Orkin et al., 2014), which is the variable *Primary School* I control for. In other words, part of the impact of HIV on gold production is channelled through education. Therefore, what I am capturing in this analysis are the “direct” effects of HIV on production, i.e. net of its effect through human capital. Looking at an additional

measure of human capital, unemployment has been included as an indicator of diminishing human capital, as time during unemployment is spent away from learning and maintaining skills on the job (Matangi, 2006). “*Unemployment*” is measured as the share of the labour force that is without work but is available and seeking employment.

Finally, I also control for migration (“*Migcap*”). As discussed in the literature review, there is a large amount of migration in the gold mining industry, most significantly across the bordering countries of South Africa (Baltazar et al., 2015; Barwise et al., 2013; Corno & De Walque, 2012). Not only does migration increase the range of human contact and the spread of HIV, but migrant workers are displaced from their families and may become subject to a lifestyle involving transactional sex. However, migrant workers bring a positive source of human capital to the mining industry with their skills from previous mining work. Peri (2012) finds that migration increases productivity and efficiency in task specialisation in both highly skilled and unskilled workers.

### **2.3.3 Descriptive Statistics**

Table 4 outlines descriptive statistics for all variables included in the analysis. Focusing on the key variables, the dependent variable, gold production, ranges from 0 to 523.8 tonnes, with a mean of 17.2 tonnes, and a standard deviation of 57.1 tonnes. To set this in a global context, in 2017, the latest year in the sample, the global gold production was 3,230 tonnes, thus the total gold production in Africa reached 21% of the global gold production (USGS, 2017).

The mean HIV prevalence in the sample is 4.6%, with a standard deviation of 6.1%. In comparison, the global HIV prevalence results from the same period are 0.8% in 2017 (WDI, 2017). This comparison demonstrates an extremely high disease burden in Sub-Saharan Africa, as shown in the sample. UNAIDS reports place 43% of all new global HIV infections in eastern or southern Africa in 2017 (UNAIDS, 2017).

There are some missing observations in the panel. In some countries, HIV data is unavailable, causing them to immediately drop out of the panel as I run my analysis, as in the case of the Seychelles and São Tomé and Príncipe. Other countries, such as Eritrea and South Sudan, have not been independent countries for the entirety of the panel. Some variables are missing higher percentages of raw data than others, including migration (missing

13.1%), consumption (missing 11.6%), and primary schooling (missing 22.1%).

Presented in Figures 6–8 and 9–11 are maps of Africa, outlining the change in the distribution of gold production and HIV prevalence over time, respectively by quartile, in 1990, 2003, and 2017. Examining the most recent data in 2017, most notably we see that the three countries in the highest quartile of gold production and in the highest quartile of HIV prevalence are South Africa, Zimbabwe, and Tanzania. In North Africa, Western Sahara, Morocco, Algeria, Tunisia, Libya, Djibouti, and Egypt are excluded from the analysis as they are not considered part of Sub-Saharan Africa, as defined by the World Development Indicators (WDI, 2017).

**Table 1**  
*Data Descriptions – Key Variables*

| Variable                                                   | Unit of Measure                                             | Source                                                                                                       | Description                                                                                                                                                                                                                                                                                                                                                                                                                         |
|------------------------------------------------------------|-------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gold production ( <i>Gold</i> ),<br>outcome variable       | Tonnes of gold (Au)<br>content                              | U.S. Geological Surveys, <i>USGS Minerals Yearbook</i> 2017, Volume III, Area Report – International, Africa | <i>USGS Minerals Yearbook</i> provides detailed annual mineral production by country. The USGS is the sole scientific bureau of the United States Department of Interiors. <i>The Mineral Yearbook</i> statistics on world mineral production are compiled annually on approximately 90 commodities, including gold.                                                                                                                |
| HIV prevalence ( <i>HIV</i> ),<br>key independent variable | Prevalence of HIV, total<br>(% of population aged<br>15–49) | WDI Source: UNAIDS estimates                                                                                 | Prevalence of HIV refers to the percentage of people aged 15–49 who are infected with HIV. This is a measure of the rate of infectiveness in a country's population. The models take into account reduced infectivity among people receiving antiretroviral therapy (which is having a larger impact on HIV prevalence and allowing PLHIV to live longer) and allow for changes in urbanisation over time in generalised epidemics. |

**Table 2**  
*Data Descriptions – Economic Controls*

| Variable                                             | Unit of Measure                                                              | Source                                                                                                         | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|------------------------------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Consumption Expenditure ( <i>Consumption</i> )       | Final consumption expenditure (% of GDP)                                     | WDI Source: World Bank national accounts data, and OECD National Accounts data files                           | Final consumption expenditure (formerly total consumption) is the sum of household final consumption expenditure (private consumption) and general government final consumption expenditure (general government consumption). This estimate includes any statistical discrepancy in the use of resources relative to the supply of resources.                                                                                                                                                                                                                                                                                                                       |
| Trade Openness ( <i>Open</i> )                       | Exports + Imports of goods and services (% of GDP)                           | WDI Source: World Bank national accounts data, and OECD National Accounts data files                           | Active trading market critical as mining production largely intended for exportation; looking at the broader research on productivity, trade is a significant determinant of productivity. Exports/imports of goods and services represent the value of all goods and other market services provided/received to/from the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, licence fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees, investment income, and transfer payments. |
| Country Size ( <i>Countrysize</i> )                  | Land area (sq. km)                                                           | WDI Source: Food and Agriculture Organisation, electronic files and website                                    | Land area is a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes.                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Telephone Infrastructure ( <i>Telinfrastucture</i> ) | Fixed telephone subscriptions (per 100 people)                               | WDI Source: International Telecommunication Union, World Telecommunication/ICT Development Report and database | Fixed telephone subscriptions refer to the sum of active number of analogue fixed telephone lines, voice-over-IP (VoIP) subscriptions, fixed wireless local loop (WLL) subscriptions, ISDN voice-channel equivalents, and fixed public payphones.                                                                                                                                                                                                                                                                                                                                                                                                                   |
| GDP per capita ( <i>Gdpcap</i> )                     | GDP per capita, inflation adjusted to US\$ million, measured in 2003 dollars | WDI Source: World Bank National Accounts data, and OECD National Accounts data files                           | GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy, plus any product taxes and minus any subsidies not included in the value of the products. Current US\$ have been adjusted to real dollars, measured in 2003 dollars, using the Consumer Price Index.                                                                                                                                                                                                                                                                                                          |

**Table 3**  
*Data Descriptions – Political Factors and Human Capital*

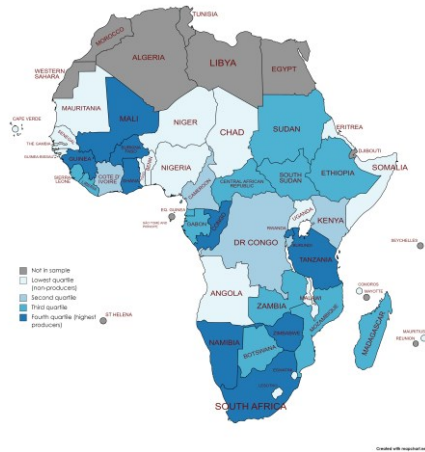
| Variable                                    | Unit of Measure                                                                                      | Source                                                                                                          | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------------------|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Political Factors</b>                    |                                                                                                      |                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Democracy ( <i>Democracy</i> )              | Institutionalised Democracy                                                                          | Polity IV Project (Marshall et al., 2015)                                                                       | Democracy is conceived as three essential, interdependent elements. One is the presence of institutions and procedures through which citizens can express effective preferences about alternative policies and leaders. Second is the existence of institutionalised constraints on the exercise of power by the executive. Third is the guarantee of civil liberties to all citizens in their daily lives and in acts of political participation. The democracy indicator is an additive 11-point scale (0–10). |
| Autocracy ( <i>Autocracy</i> )              | Institutionalised Autocracy                                                                          | Polity IV Project (Marshall et al., 2015)                                                                       | Polity IV defines autocracy operationally in terms of the presence of a distinctive set of political characteristics. In mature form, autocracies sharply restrict or suppress competitive political participation. Their chief executives are chosen in a regularised process of selection within the political elite, and once in office they exercise power with few institutional constraints. An 11-point autocracy scale is constructed additively.                                                        |
| <b>Human Capital</b>                        |                                                                                                      |                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Primary Schooling ( <i>Primary School</i> ) | Gross enrolment ratio, primary, both sexes (%)                                                       | WDI Source: United Nations Educational, Scientific, and Cultural Organisation (UNESCO) Institute for Statistics | Gross enrolment ratio is the ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Primary education provides children with basic reading, writing, and mathematics skills along with an elementary understanding of such subjects as history, geography, natural science, social science, art, and music.                                                                                                                |
| Unemployment ( <i>Unemployment</i> )        | Unemployment, total (% of total labour force) (modelled ILO estimate)                                | WDI Source: International Labour Organisation, ILOSTAT database. Data retrieved in March 2017                   | Unemployment refers to the share of the labour force that is without work but available for and seeking employment.                                                                                                                                                                                                                                                                                                                                                                                              |
| Migrant Remittances ( <i>Migcap</i> )       | Migrant remittance outflows per capita, inflation adjusted to US\$ million, measured in 2003 dollars | World Bank, Migration and Remittances Data, Annual Remittance Data                                              | Migrant remittances are measured as the sum of two items in the International Monetary Funds Balance of Payments Statistics Yearbook: i) personal transfers, ii) compensation of employees, and iii) migrant transfers (i.e. capital transfers between resident and non-resident households). Current US\$ have been adjusted to real dollars, measured in 2003 dollars, using the Consumer Price Index.                                                                                                         |

**Table 4**  
*Summary Statistics*

|                                                                                        | Mean        | SD          | Min       | Max           | N   |
|----------------------------------------------------------------------------------------|-------------|-------------|-----------|---------------|-----|
| Gold, production measured in tonnes                                                    | 17.168      | 57.073      | 0.000     | 523.809       | 632 |
| HIV prevalence, % of population aged 15–49                                             | 4.559       | 6.068       | 0.100     | 26.300        | 632 |
| Final consumption expenditure (% of GDP)                                               | 86.968      | 16.415      | 31.717    | 166.922       | 632 |
| Trade openness, exports, and imports as % of GDP                                       | 66.445      | 28.151      | 19.101    | 161.894       | 632 |
| Country size, land area (sq. km)                                                       | 546,616.639 | 558,426.345 | 1,861.000 | 2,376,000.000 | 632 |
| Telephone infrastructure, fixed telephone subscriptions per 100 people                 | 2.522       | 5.444       | 0.018     | 32.669        | 632 |
| GDP per capita, inflation adjusted to US\$m, in 2003 dollars                           | 1589.434    | 2701.461    | 97.794    | 27140.494     | 632 |
| Democracy, 0–10 scale                                                                  | 4.014       | 3.441       | 0.000     | 10.000        | 632 |
| Autocracy, 0–10 scale                                                                  | 1.891       | 2.089       | 0.000     | 8.000         | 632 |
| Primary schooling, enrolment ratio, regardless of age, to primary school age           | 95.387      | 25.816      | 26.746    | 156.404       | 632 |
| Unemployment, % of total labour force                                                  | 7.255       | 6.490       | 0.285     | 33.473        | 632 |
| Migrant remittances, outflows per capita, inflation adjusted to US\$m, in 2003 dollars | 11.184      | 34.747      | 0.000     | 433.497       | 632 |

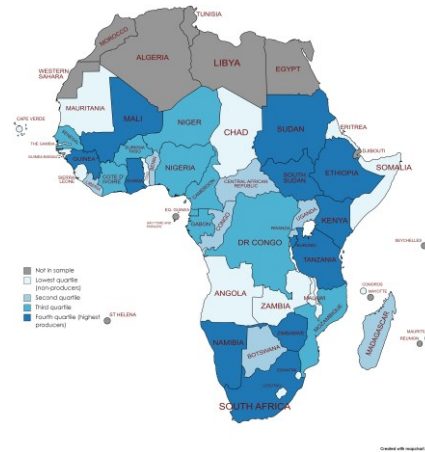
**Figure 6**

*Gold Production – 1990*



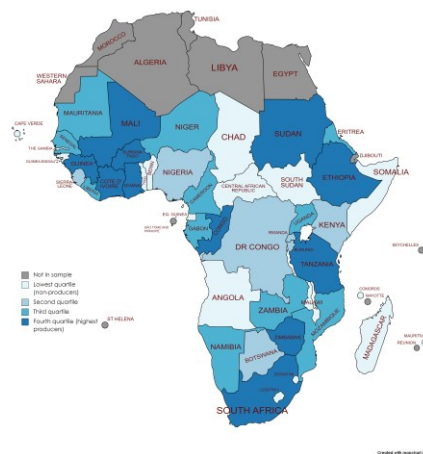
**Figure 7**

*Gold Production – 2003*



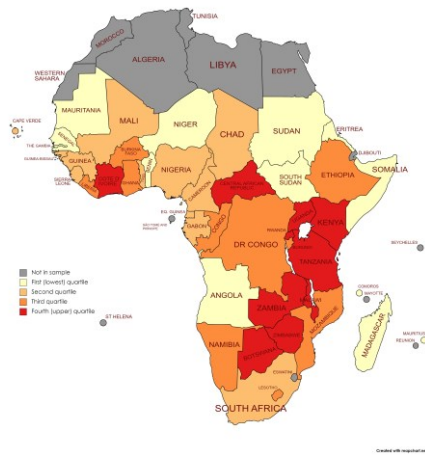
**Figure 8**

*Gold Production – 2017*

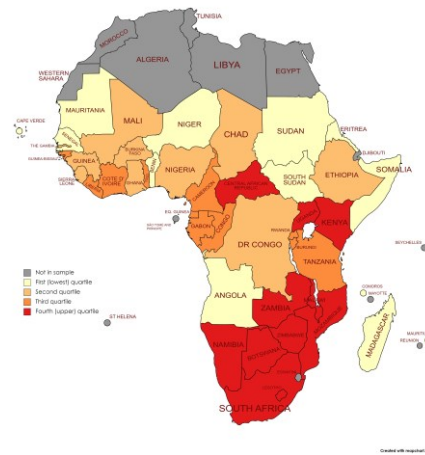


Note: Quartiles as per USGS production results (USGS, 2018). Sudan and South Sudan are treated the same in 1990 and 2003, before the countries separated in 2011. Eritrea gained independence in 1991; 1990 values are estimated. The years 1990 and 2017 are the beginning and end points of the sample; 2003 is the midpoint.

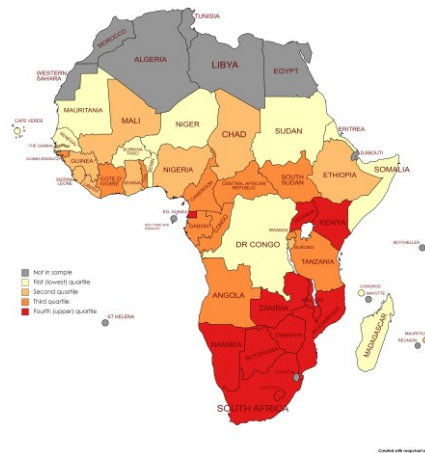
**Figure 9**  
*HIV Prevalence – 1990*



**Figure 10**  
*HIV Prevalence – 2003*



**Figure 11**  
*HIV Prevalence – 2017*



Note: Quartiles as per latest UNAIDS estimates (WDI, 2017). Sudan and South Sudan are treated the same in 1990 and 2003, before the countries separated in 2011. Eritrea gained independence in 1991; 1990 values are estimated. The years 1990 and 2017 are the beginning and end points of the sample; 2003 is the midpoint.

## 2.4 Methodology

### 2.4.1 Naïve Estimator and Endogeneity

The relationship between HIV prevalence and gold production is estimated with the following specification via pooled ordinary least squares (OLS):

$$y_{it} = \alpha + \rho H_{it} + \beta X_{it} + c_i + v_t + c_{it}, \quad (1)$$

where  $y_{it}$  denotes gold mining production in country  $i$  in year  $t$  measured in tonnes.  $H_{it}$  is the HIV prevalence in country  $i$  in year  $t$ , measured as the percentage of individuals with HIV in the country-level population aged 15–49.  $\rho$  is the coefficient of interest that conveys the impact of a 1% change in HIV prevalence in tonnes of gold production. A normal distribution is assumed for the robust error term,  $c_{it}$ , clustered by country. The analysis controls for a range of country-specific time variants,  $X_{it}$ , that have been found to correlate with mining production and/or sectoral productivity. The controls are those discussed in detail in the Data section, 2.3.  $c_i$  and  $v_t$  represent country and time fixed effects. Due to the length of the panel and the changing landscape of African countries the panel is unbalanced, most notably following the creation of South Sudan in 2011 and Eritrea in 1993. All other countries span the full panel from 1990 to 2017.

There is a reverse causality inherent in the pooled OLS estimation of the relationship between HIV prevalence and gold mining production. HIV exerts a direct causal influence on gold mining production through losses in productivity related to absenteeism and presenteeism (Habyarimana et al., 2010; Murray et al., 2005; Sonnenberg et al., 2011; Thomas et al., 2019), as well as employee costs of disease treatment (Matangi, 2006). Also, the mining industry creates working and living environments that accelerate the spread of HIV (Baltazar et al., 2015; Barwise et al., 2013; Campbell, 1997; Corno & De Walque, 2012). Additionally, there are further problems as panel data contain repeated observations on the same country unit, which are unlikely to be independent and will thus be correlated.

All of these factors indicate that using a naïve estimator will lead to bias if an appropriate methodology is not used to take into account these issues of reverse causality. Thus, to identify the causal impacts of HIV on gold production, I implement Arellano-Bond estimation.

### 2.4.2 Arellano-Bond Estimator

To address the issues of endogeneity and correlation of errors in pooled OLS, I use an Arellano-Bond (A-B) estimator. Additionally, this method offers gains in efficiency and provides a consistent estimator (Arellano & Bond, 1991). Arellano-Bond is a generalised method of moments (GMM) estimator, specifically a differenced GMM, which makes use of internal instruments to solve the problem of endogeneity (Arellano & Bond, 1991). Specifically, a dynamic panel model is used, then first differenced, and lagged levels of the regressors are utilised as instruments.

To correct for endogeneity, internal instruments are employed. In instrumenting the lagged dependent variable, one must lag back one period deeper than the lagged dependent regressor, for example using  $H_{i,t-3}$  or earlier. Multiple instruments may be used as deeper lags are utilised, improving the efficiency of the A-B estimator.

The base equation of Arellano-Bond is the following:

$$y_{it} = \alpha + \rho H_{it} + \beta X_{it} + \delta y_{i,t-1} + c_i + v_t + c_{it}, \quad (2)$$

where  $y_{it}$  is the dependent variable, gold production.  $H_{it}$  represents  $HIV$ .  $X_{it}$  is a vector of controls and a lag of gold production, and  $y_{i,t-1}$  is included as a regressor, thus enabling this to be defined as a dynamic model.  $c_i$  and  $v_t$  represent country and time fixed effects, and  $c_{it}$  is a robust error term, clustered by country. Country effects are systematic, time-invariant differences between countries. Time effects are common to all countries and take into account anything that would have uniformly impacted all – for example, any external impacts on the gold market.

Consider the differenced version of this equation:

$$y_{it} - y_{i,t-1} = \rho(H_{it} - H_{i,t-1}) + \beta(X_{it} - X_{i,t-1}) + \delta(y_{i,t-1} - y_{i,t-2}) + c_i - c_i + v_t - v_{t-1} + c_{it} - c_{i,t-1} \quad (3)$$

As the country fixed effects  $c_i$  are time-invariant, these terms fall out after first differencing:

$$y_{it} - y_{i,t-1} = \rho(H_{it} - H_{i,t-1}) + \beta(X_{it} - X_{i,t-1}) + \delta(y_{i,t-1} - y_{i,t-2}) + v_t - v_{t-1} + c_{it} - c_{i,t-1} \quad (4)$$

In addition to any time-invariant variables, any random or fixed heterogeneity is swept from the model after first differences are removed. Any associated time-invariant omitted

variable bias is removed (Baum, 2004).  $y_{i,t-2}$  and deeper lags are utilised as instruments for the lagged dependent variable.  $H_{i,t-3}$  and deeper lags are also used as instruments.

The A-B estimator is a special estimator in that it is able to correct two different problems created by the inclusion of the lagged dependent variable, included as a regressor in a dynamic panel model (Arellano & Bond, 1991; Kottaridi, 2005). This differs from a standard OLS where a lagged dependent variable is not included as a regressor as it would necessarily be correlated with the error term. Arellano-Bond corrects for the following issues: (1) the lagged dependent variable as a regressor gives rise to a necessary correlation with the error term, giving rise to endogeneity; (2) HIV is determined simultaneously with the dependent variable, gold, giving rise to reverse causality, a more specific source of endogeneity (Wooldridge, 2010); (3) removing the effects of any mediating variables (Bocoum et al., 2019; Oehmke et al., 2020; Tøge & Blekesaune, 2015).

The GMM solves both issues. For example, where the differenced equation gives rise to correlation with the error term, if I use  $y_{i,t-2}$  as an instrument for  $y_{it} - y_{i,t-1}$ , as shown below, this would imply that  $E(y_{i,t-2}, (c_{i,t} - c_{i,t-1})) = 0$ . In the case of the differenced lagged dependent variable ( $y_{i,t-1} - y_{i,t-2}$ ), an internal instrument may be lagged just one level back – for example,  $y_{i,t-3}$ . This is because lagged dependent variables included as regressors are considered predetermined variables, sequentially exogenous, independent of current disturbances, but influenced by past, and possibly future, values of  $H_{it}$  (Kottaridi, 2005; Leszczensky & Wolbring, 2022; Roodman, 2009). For the A-B method to hold, it is expected for there to be a first-order autocorrelation of errors (“AR(1)”), and it is necessary for there to be no serial second-order autocorrelation of errors (“AR(2)”).

The Arellano-Bond models in this chapter were constructed using Roodman’s `xtabond2` command in Stata 16 (Roodman, 2009). `xtabond2` allows one to specify predetermined, endogenous regressors in addition to the lagged dependent variable, which are treated as GMM instruments and lagged at a deeper level. Strictly exogenous variables serve as their own instrument. The model is designed to use only internal instruments. More instruments were not included as introducing too many instruments presents the risk that they are picking up stronger feedback effects, as is tested in the Hansen-Sargan test of overidentifying restrictions (Sargan, 1958), which tests whether the set of instruments is appropriate. The null for the Hansen-Sargan test is to examine whether the set of

instruments being used are appropriate, and that the overidentifying restrictions are valid.

For the same reason, the models presented limit lags to a specified number of years. Additionally, the `xtabond2 collapse` command is utilised, which creates one instrument for each variable and lag distance, rather than one for each time period, variable, and lag distance. This eliminates any bias that arises as the number of instruments climbs toward the number of observations. When there are too many instruments, they tend to overfit the instrumented variables and bias the results toward those of OLS (Roodman, 2009).

The Results section, 2.5, presents two ordinary least squares results analyses. “OLS-1” is included as a naïve base case model. “OLS-2” includes covariates. Additionally, two Arellano-Bond analyses are presented, “A-B1” and “A-B2”. Model A-B1 limits lags to eight years, and A-B2 limits lags to five years. It is always a challenge in Arellano-Bond to choose the appropriate length of lags, and it is necessary for this decision to not be arbitrary (Neumayer, 2004). Serial correlation can easily be a problem in priced commodity markets, such as gold, where predicting commodity price may be influenced by significant pricing changes in previous years (Campbell et al., 1993). Additionally, one does not want to lose too many observations by lagging too far back, which is referenced by many researchers if they acknowledge their decision-making process on lags, although there is no hard-and-fast rule on what exactly this observation loss to panel length ratio should be. Thus, based on relevant papers I found that cited their lag-to-panel ratio, including, but not limited to, Gomez and De Cos (2008) and Yoganarasimhan (2012), I did not lag past 30% of my 27-year panel; thereby limiting me to eight years at the maximum. Next, I looked for significant spikes or falls in the gold pricing market that might cause any serial correlation in the errors. Looking at monthly data at the beginning of each year, 2009 had the lowest gold price in the latest eight-year period of my panel (USD 813 per troy ounce), and 2012 had the highest price (USD 1,738 per troy ounce). Thus, as these were outliers and could have potentially erroneously driven the error terms in other years, I chose to present the analysis lagging at five and eight years, for robustness purposes.

The Arellano-Bond method enables us to look at the long-run causal impact of HIV on gold, rather than simply using a fixed effect panel. In both A-B models, all other covariates besides HIV and the lagged dependent variable are treated as exogenous and instrument themselves.

## 2.5 Results

Table 5 presents the OLS-1, OLS-2, A-B1, and A-B2 models. Additionally, a stepwise regression of the A-B2 analysis follows in Table 6. The OLS-1 and OLS-2 models are included for baseline, comparative purposes. A standard OLS model is insufficient to consider any possible unobserved heterogeneity that could be addressed through first differencing, such as through Arellano-Bond, so it is unsurprising to see such inflated magnitudes on the coefficients of HIV in OLS-1 and OLS-2. However, it is comforting to find the coefficients in the same direction as the two A-B models. The OLS-1 column presents the ordinary least squares result, i.e. the naïve estimation, indicating that an increase in HIV prevalence of 1% causes an annual loss of 9.724 tonnes (Table 5; Model OLS-1;  $p > 0.10$ ). OLS-2 includes covariates so as to eliminate any omitted variable bias. The results in Table 5 indicate that an increase in HIV prevalence of 1% causes a significant reduction in gold production by 9.382 tonnes (Table 5; Model OLS-2;  $p < 0.10$ ), robust to a variety of relevant exogenous controls.

The A-B1 model, which limits lags to eight years, demonstrates a negative impact of HIV on gold, indicating that a significant increase in HIV prevalence of 1% causes an annual loss of 2.586 tonnes of gold (Table 5; Model A-B1;  $p < 0.10$ ). Additionally, the A-B2 model, limiting instrument lags to five years, shows a negative impact of HIV on gold, indicating that an increase in HIV prevalence of 1% causes an annual loss of 2.915 tonnes of gold, significant at the 10% level (Table 5; Model A-B2;  $p < 0.10$ ). In comparing the Arellano-Bond estimation to OLS-1 and OLS-2, a downward, naïve bias is present in the OLS models. Excluding OLS-1, which includes no covariates, all models in Table 5 are presented including all of the controls: *Consumption*, *Open*, *Countrysize*, *Gdpcap*, *Migcap*, *Telinfrastucture*, *Democracy*, *Autocracy*, *Unemployment*, and *Primary School*. Stepwise results of the A-B2 model may be found in Table 6, where Models M1–M11 present results as controls are deleted individually via backwards elimination. The economic controls included in the analysis were found to be predictors of economic productivity in the literature. Each control explains a different extent of variability in gold production. Stepwise regression systematically removes variables, eliminating the least significant first, then the next least significant, and so forth. The analysis allows an understanding of which covariates have the strongest impact on the dependent variable (Goodenough et al., 2012). Examining

Table 6, as covariates with the least significance are eliminated, we see that *Autocracy*, *Democracy*, *Open*, and *Unemployment* are the most significant predictors of gold production. One potential limitation of this approach is that the removal of less significant predictors may artificially inflate the significance of the remaining predictors (Goodenough et al., 2012). In all models, the autoregression tests remain stable, indicating significant first-order and no second-order autoregression.

Looking at the complete list of covariates in Model A-B2 in Table 5, telephone infrastructure and primary school enrolment have a positive effect on gold production, as is suggested by the literature (Aker & Mbiti, 2010; Barro, 1991; Bates, 2004; Buccirossi et al., 2013; Jalles & Tavares, 2015; Jedwab & Moradi, 2016; Mankiw et al., 1992; Miller & Upadhyay, 2000). Unemployment is also positively correlated with gold production. The literature suggests that unemployment is higher in mining areas, as well as being higher while employees take the time to retrain, when needed (Freudenburg & Wilson, 2002; Mian & Sufi, 2012). Migrant remittances demonstrate a negative impact on gold production, although of a very small magnitude. This is reasonable as migrant workers may be more susceptible to HIV due to sexual interactions away from the home, and this susceptibility to HIV may cause a drop in productivity (Baltazar et al., 2015; Barwise et al., 2013; Corno & De Walque, 2012).

Country size, GDP per capita, consumption, democracy and autocracy, and openness have a negative effect on production. A larger country size may reflect increased trade costs, as demonstrated by Helpman (1987) and Stack (2009). Both GDP per capita and consumption have negative, insignificant impacts on production with a magnitude of almost zero, indicating that these variables do not have a meaningful impact in this sector (Arrow & Kruz, 2013; Barro, 1991; Devarajan et al., 1996; Jalles & Tavares, 2015; Mankiw et al., 1992; Miller & Upadhyay, 2000). Democracy and autocracy both exert a negative, significant influence on production. This is consistent with Bates (2004), who finds it possible that political instability may actually increase economic activity, as those in power may work hard to generate economic activity for personal or party gains. In the Polity IV data, from which the democracy and autocracy variables are taken, democratic and autocratic countries are said to demonstrate concomitant qualities in governing institutions, as opposed to being seen as mutually exclusive forms of governance. Thus, is it reasonable that the two variables have a significant impact on production in the same

direction (Systemic Peace, 2021). Openness of the economy is found to have a negative impact on mining, contrary to what is suggested in the literature on general economic activity (Barro, 1991; Mankiw et al., 1992; Miller & Upadhyay, 2000). It is possible, as suggested by Dowrick and Golley (2004), that the benefits of trade openness may accrue to the benefit of more developed economies.

In Appendix A, as a robustness check, in an effort to increase the observation count, I have explored a model with fewer covariates, excluding *Consumption* and *Countrysize* on the basis of their lack of significance and magnitude as shown in Table 6. In Model A-B2 I gain 46 additional observations and find that a significant increase in HIV prevalence of 1% causes an annual loss of 2.473 tonnes of gold (Tables 34 and 35 in Appendix A; Model A-B2;  $p < 0.10$ ). Looking at the bottom of all tables there are tests for first- and second-order serial correlation in the Arellano-Bond models. I see the desired effects, a necessary lack of second-order serial correlation in Models A-B1 and A-B2 (Tables 34 and 35), and an expected presence of first-order serial correlation in both models.

**Table 5**  
*Summary Regression Results*

|                   | (OLS-1)           | (OLS-2)            | (A-B1)              | (A-B2)              |
|-------------------|-------------------|--------------------|---------------------|---------------------|
| hiv               | -9.724<br>(6.483) | -9.382*<br>(5.032) | -2.586*<br>(1.567)  | -2.915*<br>(1.709)  |
| L.gold            |                   |                    | 0.638***<br>(0.086) | 0.605***<br>(0.085) |
| consumption       |                   | -0.216<br>(0.144)  | -0.069<br>(0.055)   | -0.013<br>(0.038)   |
| open              |                   | -0.052<br>(0.106)  | -0.074*<br>(0.045)  | -0.053*<br>(0.030)  |
| countrysize       |                   | -0.000<br>(0.011)  | -0.005<br>(0.004)   | -0.005<br>(0.003)   |
| telinfrastructure |                   | 3.834<br>(3.033)   | 0.792<br>(0.518)    | 0.701<br>(0.499)    |
| gdpcap            |                   | -0.003<br>(0.003)  | -0.000<br>(0.001)   | -0.000<br>(0.001)   |
| democracy         |                   | 0.524<br>(1.274)   | -0.242<br>(0.195)   | -0.364**<br>(0.183) |
| autocracy         |                   | -0.035<br>(1.229)  | -0.585**<br>(0.286) | -0.695**<br>(0.309) |
| primary           |                   | 0.226<br>(0.175)   | 0.053<br>(0.044)    | 0.044<br>(0.050)    |
| unemployment      |                   | 4.464**<br>(2.188) | 0.747<br>(0.626)    | 1.194*<br>(0.683)   |
| migcap            |                   | -0.006<br>(0.076)  | 0.002<br>(0.018)    | -0.000<br>(0.016)   |
| Time FE           | yes               | yes                | yes                 | yes                 |
| Country FE        | yes               | yes                | yes                 | yes                 |
| AR1 z-stat        |                   |                    | 0.032               | 0.031               |
| AR2 z-stat        |                   |                    | 0.125               | 0.133               |
| Hansen p-value    |                   |                    | 1.000               | 1.000               |
| Instrument count  |                   |                    | 214                 | 154                 |
| N                 | 754               | 754                | 632                 | 632                 |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Robust standard errors in parentheses. The dependent variable is gold production in all columns. The Arellano-Bond model is a GMM estimator with country clustered robust standard errors. In all models lagged gold production is predetermined, HIV is endogenous, and these are collapsed to create one instrument for each variable and lag distance. A-B1 limits lags to eight years; A-B2 limits lags to five years.

**Table 6**  
*Regression Results – Stepwise*

| Dependent Variable: Gold Production |          |          |          |          |          |          |          |          |          |          |          |
|-------------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|                                     | (M1)     | (M2)     | (M3)     | (M4)     | (M5)     | (M6)     | (M7)     | (M8)     | (M9)     | (M10)    | (M11)    |
| hiv                                 | -2.915*  | -2.912*  | -2.937*  | -2.929*  | -2.840*  | -2.844   | -2.823   | -2.327   | -2.362   | -2.387   | -2.365   |
|                                     | (1.709)  | (1.710)  | (1.755)  | (1.752)  | (1.723)  | (1.731)  | (1.780)  | (1.450)  | (1.464)  | (1.456)  | (1.460)  |
| L.gold                              | 0.605*** | 0.605*** | 0.605*** | 0.605*** | 0.608*** | 0.608*** | 0.612*** | 0.648*** | 0.652*** | 0.656*** | 0.657*** |
|                                     | (0.085)  | (0.084)  | (0.085)  | (0.085)  | (0.084)  | (0.084)  | (0.088)  | (0.083)  | (0.084)  | (0.085)  | (0.085)  |
| autocracy                           | -0.695** | -0.694** | -0.694** | -0.692** | -0.739** | -0.733** | -0.707** | -0.664** | -0.609** | -0.274*  |          |
|                                     | (0.309)  | (0.309)  | (0.310)  | (0.312)  | (0.313)  | (0.311)  | (0.321)  | (0.271)  | (0.257)  | (0.158)  |          |
| democracy                           | -0.364** | -0.363** | -0.361*  | -0.363*  | -0.373** | -0.370*  | -0.361*  | -0.413** | -0.390** |          |          |
|                                     | (0.183)  | (0.184)  | (0.185)  | (0.189)  | (0.189)  | (0.190)  | (0.190)  | (0.184)  | (0.190)  |          |          |
| open                                | -0.053*  | -0.053*  | -0.052*  | -0.053*  | -0.053*  | -0.052*  | -0.054*  | -0.053** |          |          |          |
|                                     | (0.030)  | (0.030)  | (0.029)  | (0.029)  | (0.029)  | (0.029)  | (0.029)  | (0.026)  |          |          |          |
| unemployment                        | 1.194*   | 1.194*   | 1.208*   | 1.214*   | 1.201*   | 1.208*   | 1.192*   |          |          |          |          |
|                                     | (0.683)  | (0.678)  | (0.694)  | (0.694)  | (0.686)  | (0.691)  | (0.707)  |          |          |          |          |
| telinfrastructure                   | 0.701    | 0.689    | 0.688    | 0.679    | 0.658    | 0.649    |          |          |          |          |          |
|                                     | (0.499)  | (0.517)  | (0.522)  | (0.522)  | (0.524)  | (0.521)  |          |          |          |          |          |
| countrysize                         | -0.005   | -0.005   | -0.005   | -0.005   | -0.005   |          |          |          |          |          |          |
|                                     | (0.003)  | (0.003)  | (0.003)  | (0.003)  | (0.004)  |          |          |          |          |          |          |
| primary                             | 0.044    | 0.043    | 0.044    | 0.044    |          |          |          |          |          |          |          |
|                                     | (0.050)  | (0.050)  | (0.051)  | (0.051)  |          |          |          |          |          |          |          |
| consumption                         | -0.013   | -0.012   | -0.012   |          |          |          |          |          |          |          |          |
|                                     | (0.038)  | (0.038)  | (0.038)  |          |          |          |          |          |          |          |          |
| gdpcap                              | -0.000   | -0.000   |          |          |          |          |          |          |          |          |          |
|                                     | (0.001)  | (0.001)  |          |          |          |          |          |          |          |          |          |
| migcap                              | -0.000   |          |          |          |          |          |          |          |          |          |          |
|                                     | (0.016)  |          |          |          |          |          |          |          |          |          |          |
| Time FE                             | yes      | yes      | yes      | yes      | yes      | yes      | yes      | yes      | yes      | yes      | yes      |
| Country FE                          | yes      | yes      | yes      | yes      | yes      | yes      | yes      | yes      | yes      | yes      | yes      |
| AR1 z-stat                          | 0.031    | 0.031    | 0.031    | 0.032    | 0.032    | 0.032    | 0.031    | 0.045    | 0.045    | 0.044    | 0.044    |
| AR2 z-stat                          | 0.133    | 0.135    | 0.137    | 0.139    | 0.146    | 0.146    | 0.149    | 0.202    | 0.189    | 0.187    | 0.189    |
| Hansen p-value                      | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    | 1.000    |
| Instrument count                    | 154      | 153      | 152      | 151      | 150      | 149      | 148      | 147      | 146      | 145      | 144      |
| N                                   | 632      | 632      | 632      | 632      | 632      | 632      | 632      | 632      | 632      | 632      | 632      |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . The Arellano-Bond model is a GMM estimator with country clustered robust standard errors. This model assumes lagged gold production is predetermined and HIV is endogenous.

## 2.6 Discussion

This analysis has evaluated the causal impact of HIV prevalence on gold mining production in Sub-Saharan Africa. Based on the Arellano-Bond model (A-B2), an increase in HIV prevalence of 1% causes a significant reduction in gold production of 2.915 tonnes, corresponding to USD 118 million per annum, based on the average LBMA gold price in 2017 (LBMA, 2018) for the average country and year. This is an approximately 7% average annual decrease in mean GDP per capita across countries in the sample. My results should encourage the instigation of policy improvements in the mining industry to promote greater population health and economic gain as the spread of HIV is reduced. The mining sector was one of the first industries to openly address the issue of HIV impacting the workforce, as it began to invest in HIV prevention policies as early as the 1990s (United Nations, 2004a). On average, a mining company invests USD 1,335 a month in HIV treatment programmes (Matangi, 2006). Without such programmes, the loss of healthy life years of miners infected with HIV will continue, and economic production will be lost. The reduction of HIV transmission due to ART is well documented in the literature (Attia et al., 2009; Donnell et al., 2010; Granich et al., 2009). This should motivate private companies and governments alike to take careful counsel before deciding where investment is needed, both corporate investments into mining projects and corporate and municipal funding for infrastructure, workforce training, and health expenditures for the treatment and prevention of HIV. Ultimately, this research demonstrates that all such investments intended to reduce HIV transmission are economically beneficial; in particular, investments in ART will translate directly into economic gain, as demonstrated by the negative relationship between economic outcome and HIV prevalence in my key findings.

It is challenging to compare the results of this chapter to other work in the field. As presented in the Background and Related Literature section, 2.2, there are two different bodies of work relating to this chapter. First, there are macroeconomic papers, which focus almost exclusively on the link between health and economic growth by examining life expectancy and GDP (Barro & Lee, 1994; Barro & Sala-i-Martin, 1995; Bloom et al., 2004). Second, there are microeconomic papers, which examine the (adverse) economic impact of morbidity through two channels, absenteeism and presenteeism (Fox et al., 2004; Guinness et al., 2003; Habyarimana et al., 2010; Matangi, 2006; Murray et al., 2005; Rajaraman et

al., 2006; Rosen et al., 2004; Sonnenberg et al., 2011). However, the existing microeconomic studies focus almost exclusively on individual-level sick days. This makes it difficult to relate a country-level, extended panel data paper such as I have presented here to the existing literature. This chapter does add to the literature through the breadth of geography and extensive span of years covered and by using an estimation methodology that captures the effects of endogeneity.

As this chapter establishes, all impacts on HIV prevalence have direct, corresponding economic impacts on gold production. Efficient practices in the prevention of HIV must be implemented in the gold mining industry to prevent unnecessary losses of family, personnel, productivity, and economic output. Whilst the analysis provides a broad international perspective on the gold mining industry, I do not have the data to identify the individual HIV status of miners in the labour force, as the panel analysis is at the country level, which has proved to be a limitation of the analysis. Given the literature on mining and HIV, as described throughout this chapter, I would presume that HIV prevalence in miners would likely be greater than that at country level. If this were the case, this would indicate that my analysis is understating the impact of HIV prevalence on mining output. There is a secondary loss of information resulting from the lack of individual data, which is the loss of understanding of how many HIV-positive miners also have TB. PLHIV are more likely to become ill with TB, and underground mines are some of the highest-risk environments for TB transmission (Mallory et al., 2000; Stuckler et al., 2013, 2011). Thus, if I had had the information on HIV and TB, I might have been able to further weight the negative health effects jointly of the two conditions on gold production. One further limitation, due to the lack of individual data, is the inability to capture productivity losses in the analysis. These productivity losses may include absenteeism and presenteeism costs, pre- and post-ART (French et al., 2019). Additionally, it is expected there will be productivity losses from carers who must exit the mining industry to care for those who have fallen ill (Jefferis et al., 2008; Taylor et al., 1996).

An additional limitation is that the HIV prevalence rates used in this analysis are estimates that may not accurately represent real-world data. In Sub-Saharan African countries, as in most countries with generalised epidemics, HIV prevalence data taken from nationally representative household surveys and antenatal clinic attendees are used to measure trends in prevalence over time. There are some limitations in this data. For

example, estimates are particularly vulnerable to weak data systems, which may bias results. For instance, antenatal clinic data could produce biased estimates if women with a known positive HIV status are not included when calculating prevalence; this then also impacts on derived incidence trends (Mahy et al., 2019). UNAIDS models attempt to correct for these biases. When informed by multiple data sources and appropriate assumptions, they produce robust estimates of HIV incidence and prevalence (Mahy et al., 2019; Stover et al., 2021). In most countries in Sub-Saharan Africa, UNAIDS models utilise the Estimation and Projection Package (EPP) which constructs national and sub-national epidemic curves (Ghys et al., 2004; UNAIDS, 2021d). These UNAIDS tools allow users to define a national epidemic in terms of local group sub-epidemics. Recently, data on ART coverage has also been included in the models to further improve the accuracy of the estimates (UNAIDS, 2021d).

In concentrated epidemics, there are additional challenges as surveillance systems for hard-to-reach populations have limited coverage and the data is often not comparable over time due to changes in sampling methods. Additionally, with concentrated epidemics, paediatric HIV estimates are difficult to capture as no robust measures currently exist on the fertility of populations living with HIV (Mahy et al., 2019). In the UNAIDS models for key populations, data on population size and HIV prevalence from integrated behavioural and biological surveys are used to determine HIV prevalence trends over time (Mahy et al., 2019). These models approximate HIV incidence in specific, hard-to-reach populations, relative to the general population, intervention coverage, and the reduction in incidence among people reached by interventions. In particular, HIV incidence rates are derived from the prevalence trends after accounting for ART coverage (Stover et al., 2021).

As demonstrated in the stepwise regression analysis utilising backwards elimination, in Table 6, we see that *Autocracy*, *Democracy*, *Open*, and *Unemployment* are shown to be the most significant predictors of gold production. As mentioned in the Results section, 2.5, it is possible, however, this is taking a narrow scope, as systematically removing less significant covariates may falsely inflate the significance of the remaining covariates (Goodenough et al., 2012).

One further limitation of the model is that it uses unbalanced panel data, due to the lack of HIV data on the Seychelles and São Tomé and Príncipe, and the creation of new countries, including Eritrea in 1993 and South Sudan in 2011.

International aid foundations and donors have had an immense impact in the battle against HIV, and it is critical for multinational corporations to take necessary action to protect the progress that has been made thus far, and promote health and economic outcomes. It is unfortunate that consistent data was unavailable at the panel data level to distinguish between treatment costs incurred by employers and governments, so as to further explore the fiscal channel of these findings. The agriculture and hunting industries, and manufacturing industries in Sub-Saharan Africa, are of almost identical sectoral profitability in terms of log revenue turnover to costs (approximately 0.5) to the mining industry (International Monetary Fund, 2019), and would likely suffer from the same human capital issues. Thus, the relevance of such corporate actions extends well beyond the boundaries of the mining communities. Understanding macroeconomic impacts may raise the cost-effectiveness of public health interventions and increase the associated economic benefits to the mining sector and overall economy. This should then lead to further adoption of health interventions in the mining sector, which may be explored through macroeconomic-level cost-effectiveness analyses. A full societal perspective on the benefits of investing in HIV should include all such macroeconomic gains.

As gold production is of high economic relevance in international markets, future research may entail the examination of how HIV impacts gold available for the luxury goods market and trading markets. Mining activities impacted by HIV may also have a meaningful effect on country-wide infrastructure. I have made a note of the inclusion of the variable *Countrysize*, as an attempt to capture trade costs for those economically distant countries. It should be noted as a further limitation that this is an imperfect measure, providing more knowledge about the distance required to travel internally, and not taking into account which countries are coastal and which are landlocked. In addition to driving labour demand, which bolsters economic results, the industry activity builds up local infrastructure to facilitate transportation of workers to mining sites, both internally and across bordering country lines. Natural resources and the related government spending that these resources finance generated 32% of Africa's GDP growth from 2000 to 2008 (McKinsey & Co., 2016). Transport and telecommunications growth, developing as needed with the exploration of natural resources, contributed a further 10% to GDP growth over this same period (McKinsey & Co., 2016).

In conclusion, this research presents evidence of the detriment HIV causes to economic

productivity in the gold mining industry. The potential significant economic gains to the mining industry should be a consideration as policymakers analyse potential public health interventions in the prevention and treatment of HIV. It is in the best interest of the greater African economy, and the health of the workforce, for incentives to be aligned to create an environment that fosters individual choices promoting good health, as well as encouraging corporations to invest in their personnel. Implementing policies to advance the health of the workforce will serve to bolster local and national economies, and improve general population welfare.

### **3 Chapter 3: Does Community-based HIV Combination Prevention Impact Inequity in Healthcare Utilisation? Lessons from HPTN 071 (PopART)**

#### **3.1 Introduction**

This research explores the impact of a combination prevention trial, the PopART trial, on distributional inequity in Zambia and South Africa. Equity is a key performance metric of health systems (O'Donnell et al., 2007). Therefore, the assessment of the inequity of healthcare delivery is of key relevance for policymaking. However, despite being such a central concept, inequity analyses are less common than expected, as most current literature focuses on assessing inequalities. While the assessment of inequalities is important, they are a simple measure of distributional imbalances. Measuring inequalities does not enable us to assess whether these distributions are warranted or not.

Not all randomised controlled trials are relevant for assessing inequities. Jull et al. (2017) suggest a theoretical framework for when it is suitable to utilise such trials in such a manner. Notably, this framework cites trials to be “health equity relevant” if a trial assesses the effects of the intervention on health. This includes the PopART trial, the data from which enables me to assess individuals in the population who experience a greater health burden and less access to healthcare. In this chapter, wealth is used as just such a social determinant. When assessed in this manner, health inequalities may be labelled “inequities” when considered unfair (Jull et al., 2017; Whitehead, 1991), a framework and notation I have kept consistently with throughout this chapter.

Horizontal inequity, as measured in this chapter, qualifies inequalities within a principle of justice framework, by enabling us to assess the extent to which unequal distributions of healthcare utilisation are warranted, as perhaps they reflect different health needs or are unwarranted (O'Donnell et al., 2007). Evidence suggests there is often inequality in healthcare utilisation in relation to socio-economic characteristics, such as wealth (O'Donnell et al., 2007). For example, in both high- and low-income countries, a lack of insurance and purchasing power among the poorer generally leads to lower utilisation of healthcare than among the wealthier, despite the greater need of the poor (Gwatkin et al., 2003). Thus, horizontal inequity is a key performance metric to make value judgements with regard to the distribution of healthcare utilisation in a health system, as well as being

instrumental in assessing the distributional effects of policies and interventions in which the objective is to promote access to treatment. PopART is one such policy.

PopART is the largest community RCT of universal HIV prevention, and testing and treatment, designed with the intention of reducing community-level HIV incidence. The prevention interventions include universal voluntary HIV counselling and testing provided at the household level, the linkage of HIV-infected individuals to care, and early initiation of ART for all PLHIV (HPTN HIV Prevention Trials Network, 2021). Data was collected individually from 48,000 adults, surveyed in 21 urban and peri-urban communities in Zambia and South Africa (HPTN HIV Prevention Trials Network, 2019).

Although there is no explicitly stated aim to reduce inequality or inequity, the trial could have impacted lower or higher socio-economic groups differently, thus affecting horizontal equity in primary healthcare utilisation, which this chapter looks to explore. In the sampled trial population, HIV is more prevalent in the lower socio-economic groups. In the PopART trial, in the baseline cohort, 32.1% of PLHIV were found in the lowest wealth quintile. The poorer also face the biggest challenges in accessing prevention, diagnostics, and treatment among the population; access and utilisation of healthcare are structural factors for access to HIV testing (Bond et al., 2005). Poverty, underdevelopment, illiteracy, and gender inequity are structural barriers to HIV prevention and treatment (Amon & Kasambala, 2009; Orach & Garimoi, 2009; Van Doorslaer & Wagstaff, 1992; Wagstaff, 2000). However, the trial eliminates some of these barriers. The costs of treatment to patients are decreased as treatment is brought into the home. Opportunity and travel costs are greatly reduced, and the knowledge of treatment options is increased (Pillai et al., 2019). Prior to accessible ART initiation, notable costs to patients of accessing HIV care in South Africa, for example, include direct and indirect costs, and productivity costs, as jobs are interrupted to travel for treatment. Carer costs are involved if independent travel is not possible (Pillai et al., 2019). Due to these eliminated costs, it is possible that the PopART trial may have benefited the poorer disproportionately, thus reducing inequities in healthcare utilisation.

However, it is also possible that PopART could have widened inequities. Hargreaves et al. (2016) found that HIV-related stigma and discrimination can act as barriers to the implementation of successful HIV prevention programmes, specifically in the PopART trial. Stigma can be seen as a form of social control, in which a “difference” is turned into “inequity”, as groups with power devalue and exclude other groups from society (Parker &

Aggleton, 2003). Mateveke et al. (2016) find that in Zimbabwe, specifically, HIV-related stigma, including shame, blame, social isolation, perceived discrimination, and equity, were significantly associated with individuals with low to medium socio-economic status (SES), rather than those with high SES. Rice et al. (2017) found that HIV-related stigma acts as a barrier to HIV care visit adherence. Therefore, it could be that despite PopART being a universal intervention, engagement with the services provided may be higher among higher socio-economic groups less affected by stigma. This could have led to PopART widening pre-existing inequity in healthcare utilisation. Thus, the extent to which PopART reduces or increases inequities has not been a priori understood, although it is very important from a policy perspective. In this chapter I address this gap in knowledge by measuring horizontal inequity differences in treated and control communities, pre- and post-trial.

This work relates to a growing body of literature that assesses inequalities and inequities in low- and middle-income countries, which is explored further in the next section of this chapter. Most papers on HIV focus exclusively on inequalities. Ngandu et al. (2017) assess inequalities in the pre-antenatal registration uptake of HIV testing and find that mother-to-child transmission is more prevalent in lower-wealth groups. Haal et al. (2018) assess the impact of the ART rollout on inequalities in mortality by income and find higher inequalities in mortalities, especially in males, in lower-wealth groups. Very few papers assess inequities in health. The work that has been done has focused on child and maternal outcomes, most notably the work of Nghargbu and Olaniyan (2017), who find increasing inequities in favour of the wealthier over time (1999–2013) in maternal healthcare, and decreasing inequities in favour of the wealthier over time in terms of child healthcare. There is also an additional body of work that examines the impact of policies and interventions on inequities. Again, most research in this area focuses on maternal and child health outcomes. Zere et al. (2012) focus on interventions in line with reducing child mortality and improving maternal health, and find no inequities in child interventions, but discover that interventions aimed at mothers are found to benefit the wealthier.

I build on this literature in three significant ways. First, I have a specific focus on HIV. HIV is a key driver of mortality and morbidity in low-income countries generally, and in Sub-Saharan Africa in particular. In 2019, HIV was still a top-20 leading cause of death globally; in low-income countries it remains in the top 10 (WHO, 2021a). In 2012, 91.9 million disability-adjusted life years (DALYs) were lost worldwide because of HIV, second

only to diarrhoea in terms of morbidity from infectious disease, and seventh overall. Of this total, Africa accounted for 66.8 million DALYs lost, 72.7% of the total lost to HIV (Holmes et al., 2017). As such, numerous policies and interventions have been deployed in these settings to prevent and mitigate the impact of HIV. To date, the existing literature assessing the impact of policies and interventions on inequities has focused on drug innovation, and maternal and child health outcomes. Given the relevance of HIV in low-income countries, understanding the distributional impact of HIV interventions is of critical importance to population health and policymaking.

Second, I am the first to assess the impact of the importance of a comprehensive universal care package specific to HIV. The PopART trial utilises a broad spectrum of care, including prevention and diagnostics, notably with home testing and treatment at the individual level. I make use of individual-level data in a cluster randomised trial, collapsed at the community level, which has never been done before in inequities research. The PopART trial provides more granular data specific to HIV that are not available from other individual-level data sources such as the Demographic and Health Surveys (DHS) data used in other inequity papers, including Nghargbu and Olaniyan (2017), Yourkavitch et al. (2018), and Zere et al. (2012). Unlike the DHS, and other data sets used in the literature, PopART provides a broad source of HIV-related outcomes, as well as indicators of healthcare utilisation, including prevention, diagnostics, treatment adherence, costs, and travel time specific to HIV treatment.

Third, I improve on the literature in this area by deploying state-of-the-art inequalities and inequities methodologies, which better enable me to quantify the direction and magnitude of inequities in healthcare utilisation. This is in contrast to the existing literature, which mostly relies on the correlation between need and healthcare utilisation across different socio-economic groups and geographies. I bring a very concrete methodology to use in estimating the impact of PopART on inequity in healthcare utilisation, estimating concentration curves and indices, and utilising the health inequity index.

As such, I am able to provide new evidence on trends in Zambia and South Africa's distributional imbalances in healthcare utilisation, and the impact of a large-scale combination prevention trial on such distributions, meaningfully specific to HIV. The findings of this chapter are critical, as they provide evidence to policymakers on the equity implications of prevention trials and highlight the need for further equity-enhancing

policies in the health systems assessed.

## **3.2 Background and Related Literature**

My work contributes to two distinct yet related strands of literature: healthcare utilisation inequalities and healthcare utilisation inequities. Healthcare inequalities are distributional imbalances. Healthcare inequities are differences in healthcare deemed avoidable and unjust (Whitehead, 1991; Yourkavitch et al., 2018). The following presents the more relevant work to mine in these two fields.

### **3.2.1 Healthcare Utilisation Inequalities**

Health and healthcare inequalities have been documented for both low- and high-income countries (HIC) in economics literature.<sup>2</sup> Most of the literature has focused on assessing inequalities in high-income countries and has found a pro-rich distribution for delivery systems and specialist care. Van Doorslaer and Wagstaff (1992) and Van Doorslaer et al. (2000) assess both primary and specialist care, using data for seven to ten European countries and the US, respectively. The authors find pro-rich inequality in healthcare utilisation in specialist care. Van Doorslaer and Wagstaff (1992) find pro-rich inequality in access to care. Van Doorslaer et al. (2000) find that in all countries there is a pro-poor inequality in the distribution of primary care.

In low-income countries, existing research tends to be largely focused on specific disease areas of key public health relevance in the studied countries, including infectious diseases, mother and child health, and nutrition. Ngandu et al. (2017) focus on mother-to-child HIV transmission, measuring wealth-related inequalities in testing, specifically the uptake of HIV testing before enrolling in antenatal care. The authors use a cross-sectional, individual-level sample of 8,618 women in 2012 in South Africa to measure inequalities in early (pre-antenatal registration) uptake of HIV testing. Pro-poor, wealth-related inequalities in early HIV testing are found, suggesting that mother-to-child transmission might be heightened given the higher HIV prevalence in the lower-wealth group.

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<sup>2</sup> In this chapter I use the terms “pro-poor” and “pro-rich”. In the context of this analysis, pro-poor (or pro-rich) will be used to denote when the distribution of healthcare utilisation is disproportionately concentrated among the poor (or rich). It is important to bear in mind that, for SSA, “rich” is a relative term and may be viewed as compared to other disadvantaged communities. The term “horizontal inequity” references the degree to which utilisation is still related to income, after accounting for differences in needs across income (d’Uva et al., 2009).

Yourkavitch et al. (2018) focus on inequalities in five indicators across geographic regions for children in Sub-Saharan Africa: healthcare seeking, breastfeeding, immunisations, stunting, and mortality. The authors provide an overview of 27 African countries between 2010 and 2014, utilising DHS data to examine these indicators of child health, looking at variation both within and among countries across all indicators, and find mixed results. Among countries, under-five mortality and vaccine coverage demonstrate the greatest levels of inequality by HIV prevalence. In comparison, care seeking and stunting have relatively less unequal distributions in prevalence by country.

In Barrenho et al. (2019), the authors measure inequality in drug innovation and disease burden. Research and development activity is compared with population health and GDP across 493 therapeutic indications in 1990 and 2010, and results are mixed according to disease burden subcategory. For some, innovations are disproportionately concentrated in diseases with a high burden and a large market size, such as is demonstrated with cardiovascular, circulatory, and musculoskeletal disorders. For others, the innovation is concentrated in low-burden diseases, including mental and behavioural disorders, neonatal, and neglected tropical diseases.

Very few papers have measured the impact of an intervention on health inequalities. Haal et al. (2018), however, provide such a paper. They measure the impact of an intervention on the change in inequalities in mortality by income in South Africa pre and post the rollout of free antiretroviral therapy, examining national surveys from 2001, 2007, and 2011. The findings show a pro-poor inequality in the distribution of age- and sex-specific mortality, especially in males, between 2001 and 2006, with mortality significantly rising before the rollout of ART, and significantly falling after.

### **3.2.2 Healthcare Utilisation Inequities**

In contrast to the literature on inequalities, most of the research on health inequities focuses on high-income countries. For example, evidence for European countries shows a pro-rich bias in healthcare inequity, as demonstrated by Wagstaff et al. (1989) in Britain, Italy, and the Netherlands, as well as in the US, and by d’Uva et al. (2009) in ten countries across Europe. Lairson et al. (1995) confirm pro-rich inequity in healthcare utilisation in Australia; however, they find pro-poor inequity in Europe and the US. Jui-fen et al. (2007) measure horizontal equity for inpatient admissions in Asia and find mixed pro-poor, pro-

rich inequity results across the three countries analysed.

Work on inequities in low-income countries has been focused on both vertical inequity, i.e. inequity in healthcare financing, and horizontal inequity, i.e. inequity in healthcare access and utilisation.

In regard to the former, Asante et al. (2016) conducted a systematic review focused on health financing reforms in LMICs. The authors presented 24 studies, including 12 from SSA, and found that the distribution of healthcare benefits, as measured by healthcare utilisation, benefited the better off more than the poor. In SSA, primary health services were only marginally pro-poor. Some countries in the Asia-Pacific region were found to have made efforts towards distributing health finance towards the poor. Barrenho et al. (2017) also focus on financing, measuring inequities associated with different funding mechanisms in malaria across 94 countries, using data from 2006 to 2010. National GDP per capita is used as a proxy for economic need. Focusing on horizontal inequity, the authors find external funding from UNICEF and the President's Malaria Initiative to be the most inequitable (pro-poor), and domestic funding inequitable (pro-rich) in all years.

Inequity in access and utilisation of healthcare research has documented inequities in primary care (Lavoie et al., 2018), tertiary care (Curtis et al., 2012), and for both public and private provision (Blendon et al., 2002; Braimoh et al., 2021; Harris et al., 2011).

A substantial body of evidence relates to inequities in maternal and child health primary care (see, for example, reviews by Langlois et al. (2015), Prost et al. (2013), and Yuan et al. (2014). Langlois et al. (2015) examined 36 studies in a narrative synthesis and included ten studied in a meta-analysis, finding that rural women in the lowest socio-economic class were significantly less likely to utilise postnatal care services than urban women in the same socio-economic class. Additionally, postnatal service use was found to increase with levels of education. Prost et al. (2013) included seven trials in their study, finding that exposure to women's learning groups reduced maternal and neonatal mortality. Additionally, Nghargbu and Olaniyan (2017) examine inequity in the healthcare utilisation of maternal and child care in Uganda, as measured by antenatal visits, skilled deliveries (assisted by doctors, nurses, or midwives), and the utilisation of immunisation. The authors use data from four rounds of DHS surveys and find increasing pro-rich inequity in maternal healthcare over time, but decreasing inequity in the utilisation of child healthcare (immunisations) over time.

Zere et al. (2012) examine the impact of a variety of interventions on inequities in maternal and child health outcomes in Ghana, utilising the 2008 DHS survey. The goals of the interventions aligned with those of Millennium Development Goals 4 and 5, namely reducing child mortality and improving maternal health, respectively (United Nations, 2015). For children, a variety of health need indicators are used, including stunting, weight, and under-five mortality. For mothers, anaemia and weight are the primary indicators. A variety of interventions are examined, including the treatment of diarrhoea and receipt of vaccines among children, including receiving all basic vaccines, and sleeping under insecticide-treated nets. For women, interventions include skilled care at birth (a doctor or midwife present), deliveries in a health facility (both public and private), caesarean section, the use of modern contraceptives, and preventative treatments for malaria during pregnancy. No inequities were found in the child interventions; all interventions aimed at the mothers were found to be pro-rich, however the authors note that women in the poorest quintile use fewer such interventions.

There is additional work on inequities in LMICs, including inequity and tuberculosis (Boutilier et al., 2022; Mushtaq et al., 2011), gender and HIV (Jewkes et al., 2010; Richardson et al., 2014; Shannon et al., 2012), further studies in malaria (Onwujekwe et al., 2008, 2010), and neglected tropical diseases (Aagaard-Hansen et al., 2010; Sun & Amon, 2018). Furthermore, there is a separation in the literature of work focused on the type of health service, including primary (Lavoie et al., 2018), tertiary (Curtis et al., 2012), and private or public (Blendon et al., 2002; Braimoh et al., 2021; Harris et al., 2011). This chapter expands upon this existing body of literature on inequities in LMICs.

### **3.2.3 Research Scope**

This chapter contributes to the literature in being the first piece of research to analyse the impact of an RCT trial on distributional inequities in access to primary healthcare. The main objective of the PopART trial was to assess the impact of home-based testing and immediate ART initiation on HIV incidence (Hayes et al., 2019). However, learning about inequities may be seen as a secondary impact of the trial. While it would be plausible that the trial may have impacted inequity in healthcare utilisation, the direction of the effects are unclear. For example, in low-income countries, inequalities may be seen as a reflection of healthcare failing to reach the poor due to inequitable access

(Orach & Garimoi, 2009; Van Doorslaer & Wagstaff, 1992; Wagstaff, 2000), or a failure on the part of infrastructure. As more resources are given to the poor, and PopART brings access and knowledge into the home, one might expect an increase in healthcare utilisation for these groups of the population, resulting in an increasingly pro-poor distribution. However, it is also possible that the trial further widened inequity in primary healthcare utilisation. Evidence of stigma being prevalent among the poor suggests that stigma acts as a barrier to healthcare access in households with lower SES (Hargreaves et al., 2016; Mateveke et al., 2016; Parker & Aggleton, 2003; Rice et al., 2017). If such a stigma impact is great enough, it is possible that engagement in PopART is stronger among the rich, thus widening pre-existing, pro-rich inequities in healthcare utilisation. Ultimately, a quantitative analysis, such as is presented in this chapter, is necessary to determine the net outcome of health and utilisation inequities in Zambia and South Africa resulting from the PopART trial.

Specifically, I add to the literature in a few notable ways. My work has a specific focus on HIV, a global driver of morbidity and mortality, most notably in low-income countries. I use a concrete methodology to estimate the impact of an intervention on both inequalities and inequities, expanding beyond the work that has been done in low-income countries, which has focused on simply measuring inequalities and distributional imbalances. Lastly, I am able to make use of a rich set of individual-level data for a randomised intervention at the community level, providing a wealth of HIV-specific indicators that is not available from other commonly used sources, allowing me to draw conclusions from a nationally representative sample of the population. This chapter provides valuable insight that has not been provided before. These findings may help inform policymakers on the impacts of home-based testing and combination prevention treatment, in addition to those findings already noted about the impact of the trial on HIV incidence.

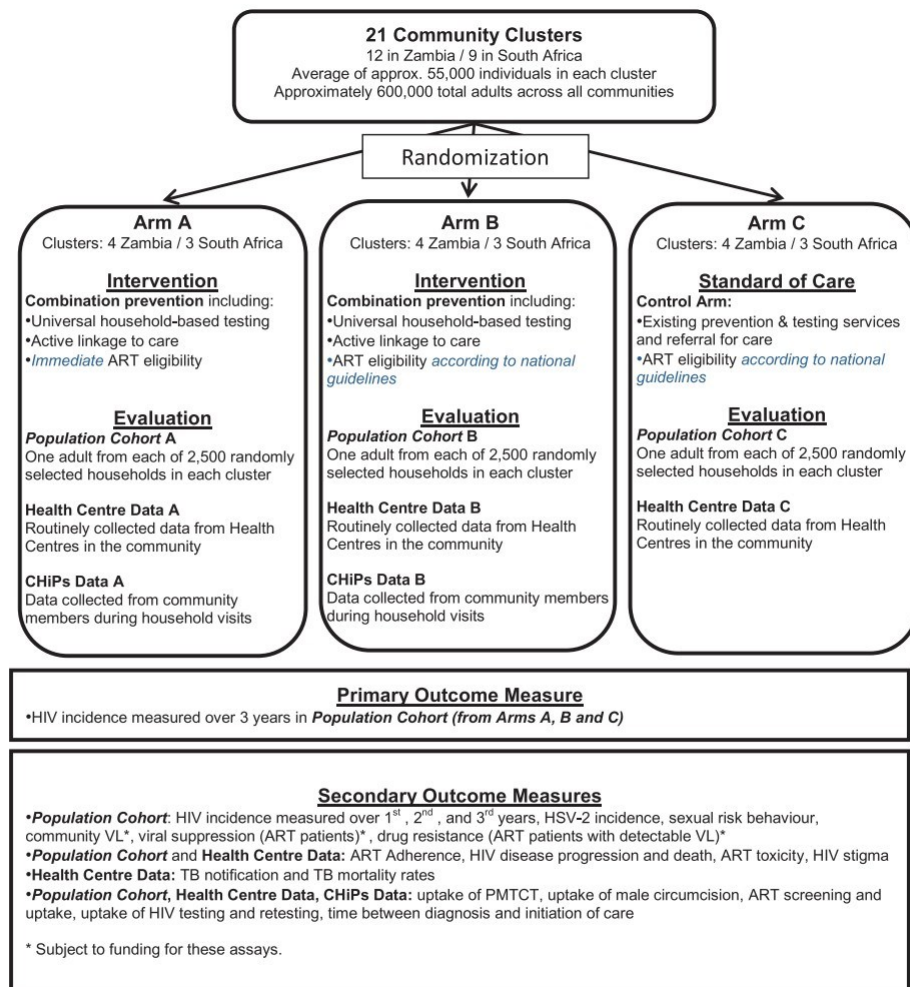
### 3.3 Data

This research makes use of data from the HPTN 071 PopART trial that took place over the period 2013–2018 in Zambia and South Africa. The trial surveys a population cohort, a random sample of 2,500 individuals in each of 21 communities (approximately 48,000 individuals in total, after attrition). These individuals were surveyed at baseline, when the intervention was delivered, and then again at 12, 24, and 36 months following the original survey. This chapter refers to the baseline survey as Wave 1, and follow-up periods as Waves 2–4. The trial is a cluster randomised trial to test the impact of combination prevention on HIV incidence, including universal voluntary testing, active linkage to care, and immediate ART initiation following a positive HIV test (Hayes et al., 2014). The 21 communities were placed into seven triplets: four in Zambia and three in South Africa. The purpose of assigning communities to matched triplets was to reduce between-community variance in baseline HIV incidence, which is assumed to be correlated with HIV prevalence. Additionally, the triplets were matched based on geographical proximity, and implementing partners for HIV services (Hayes et al., 2014).

I include here a full outline of the trial design and arms, found below in Figure 12. There are three arms within the trial. Each triplet is randomised into Arms A, B, and C.

Thus, after this randomisation, there are seven clusters, or communities, in each arm. Arms A and B are the treatment arms. Arm A has received the full intervention package, including home testing, immediate ART initiation following a positive diagnosis, and active linkage to care. Arm B was designated to receive a partial intervention, including universal testing and linkage to care, and national ART guidance. However, in 2015, the WHO updated guidelines to update national guidance to immediate ART initiation. This was implemented at the beginning of April 2016 in Zambia, and October 2016 in South Africa (WHO, 2015). Thus, the change in guidelines rendered Arms A and B the same as of the second PopART round. Arm C is a control group, receiving the standard of care provided in these communities. This includes existing prevention and testing services and referral for care, and ART eligibility according to national guidelines (Hayes et al., 2014). Thus, following the WHO guideline change, all three arms in the trial qualified for immediate ART eligibility, so, as seen in Figure 12, the key difference between control Arm C and treatment Arms A and B was the testing and additional data collected by community HIV providers (CHiPs) during

**Figure 12**  
Summary of Trial Design



Source: Hayes et al. (2014)

household visits (Hayes et al., 2014). As laid out in the trial protocol (Hayes et al., 2014), the home-based testing package carried out by the CHiP team would support the CHiPs in their responsibility for ensuring effective linkage to care for any HIV-positive individuals who had not presented themselves at a clinic for care within a defined period. Additionally, CHiPs were to encourage HIV-negative men to present to locally available services for voluntary medical male circumcision (VMMC).

Households were randomly selected for the survey within communities, and one adult was randomly selected within each randomly selected household to be part of the population cohort. These individuals, if available, were then re-interviewed over time at the follow-up surveys. If they were not available, another member of the household was randomly chosen. Due to the nature of the trial design, I am able to compare across trial arms, over time. There is some attrition in the trial. The primary statistical analysis of the trial, examining any trial impacts on incidence, takes into account the different sampling probabilities resulting from the selection of one individual, irrespective of household size (Hayes et al., 2014). In the trial protocol, Hayes et al. (2014) note that attrition leads to some selection bias in the estimate of HIV incidence. As a result, every effort was made to retain and track population cohort participants to minimise the effect of selection bias on effect estimates. Looking at the four waves in Table 7, for individuals providing final HIV test results, we see 37,128 individuals in Wave 1, 27,558 in Wave 2, 27,896 in Wave 3, and 26,778 in Wave 4. In South Africa, follow-up interviews were extended beyond traditional weekday work hours to ensure as high a retention rate as possible (Bell-Mandla et al., 2020). Additionally, to smooth the effects of attrition, a proportionate number of new respondents were interviewed in Waves 2 and 3, so the end result is net attrition in the data.

I use this data to construct my three key variables: Final HIV Status, Primary Healthcare Utilisation, and a Wealth Index. Final HIV Status and Healthcare Utilisation are used to measure the distributions of health burden and primary healthcare utilisation, and wealth is used as a ranking variable. For the Final HIV Status (“HIV”), I construct a binary disease-specific variable for each individual that enables the measurement of prevalence in the sample population. This is built based on HIV status data collected during the trial through testing. To collect this data on HIV status in the trial, CHiPs visited households in pairs, offering annual testing and retesting using HIV rapid tests. Participants were initially

screened for HIV infection by fingerprick using the Alere Determine HIV-1/2 test (Alere International). If the test was found to be positive, the results were further tested with the Uni-Gold HIV test (Trinity Biotech). If discordant results were found, an HIV testing algorithm was followed that adhered to national guidelines (Hayes et al., 2017). The uptake and results of the HIV testing were recorded on an electronic data capture (EDC) device. This data was used to provide the information for the variable *HIV*.

Primary healthcare utilisation (“*Util*”) was included by the household survey carried out by the CHiPs. The variable is proxied by the question: “In the last three months, have you sought outpatient medical care for yourself, not including any visits for which you were hospitalised?” This question was asked to a random subset of the individuals in the population cohort in each of the four waves. Approximately 20% of the sample answered the subset of questions including the healthcare utilisation query. In each wave, the question was posed to a different subset of individuals. Both *HIV* and *Util* are binary variables. To account for the nature of such data, *HIV* and *Util* are presented as mean values per wealth index in all concentration curves, as presented in the Results section, so both axes present a population-level measure.

Finally, my ranking variable (“Wealth”) is built from wealth indices formed for each country, in each time period of the different waves, and is used to estimate the socio-economic status associated with the health need in that period. The wealth index was constructed via a principal component analysis (PCA) for each country, taking the means of building counts, floor panels, and sanitation panels, which remain stationary over the four waves of the trial, and also cellphones, bicycles, cars, home electricity, televisions, refrigerators/freezers, computers or laptops, and CDs or MP3 players, which are variable over the four trial waves. My primary analysis uses the wealth index that is repeated in each wave. It is important to understand the stability of the wealth index, so any results I find regarding the impact of the trial on the distributional inequity of HIV and healthcare utilisation are truly the results of the trial, and are not compounded by any changes over time in the wealth distribution. Given the stationary components of the PCA, a Friedman test was conducted, by wave and treatment group, to test whether the distribution of wealth changes using this variable wealth measure, as compared to ranking using the wealth index as per the baseline value, which does not change, taking on a constant value for each wave. The test concludes in every wave, in both the treatment and control populations, that the

distributions are not the same ( $p < 0.001$  in all cases). The decision was taken to allow the distribution of wealth to vary over the waves, in keeping with the movement of HIV prevalence and healthcare utilisation, which also change each wave. As a robustness check, the analysis was also run ranking by the baseline wealth in each wave. This analysis can be found in Appendix C. The results are similar, and not inconsistent with my main specification, finding significant results nearer to the end of the trial. Thus, I find the analysis to be robust to the choice of wealth variable.

Tables 7–9 present summary statistics for the total sample, split by treatment and control groups, by wave, and by country. Due to the combination of Arms A and B, we see approximately twice the observation count in the treatment group compared to the control group. I have separated out the data by baseline, meaning pre-trial data (Wave 1), and post-trial initiation results, which is an average of Waves 2–4. On average, for post-trial initiation, there is a lower HIV prevalence in the treatment group, and slightly less healthcare utilisation. Additionally, I see on average a slightly higher wealth index in the treatment group, post-trial initiation, than in the control group. “Baseline HIV” is included as a descriptive statistic to note prevalence rates before treatment was initiated. Additionally, it is of interest as the best available estimates of adult HIV prevalence were used to stratify communities into triplets, given that baseline HIV incidence is assumed to be correlated with baseline HIV prevalence (Hayes et al., 2014). In Tables 7–9, Baseline HIV varies by wave due to attrition, and the varying sample size in each wave. “Final HIV status” is the variable used in the analysis.

Looking at the total observation count for my key variables at baseline, Zambia makes up 51.7% of the observations for HIV prevalence, and 52.7% of the observations for healthcare utilisation. Comparing post-trial initiation HIV prevalence between Zambia and South Africa, there is a significantly larger gap between the treatment and control groups in South Africa. Specifically, the post-trial initiation treatment group in Zambia (averaged “Waves 2–4” in Table 8) has a mean prevalence of 23.6%, and the control group has a prevalence of 23.3%. In contrast, the post-trial initiation treatment group in South Africa (averaged “Waves 2–4” in Table 9) has a prevalence rate of 21.8%, and the control group has a prevalence of 25.5%. Similarly, for healthcare utilisation there is a greater spread between the treatment and control groups for South Africa. In Zambia, there is a tight margin, with post-trial initiation

mean healthcare utilisation for the treated at 11.5%. The mean utilisation for the post-trial initiation control group is 11.6%. In contrast, in South Africa, the post-trial initiation mean healthcare utilisation for the treated is 5.1%, and the post-trial initiation mean for the control group is 6.6%.

Observing the difference in means t-tests of the key variables, the treated and untreated populations were tested pre-intervention, as well as post-intervention. No significant differences were found in the pre-intervention data, as one would expect given the randomised nature of the trial. You will note that only six triplets have been included in the difference in means t-tests and, in fact, in all analyses in this chapter. Triplet 2, in Zambia, was excluded as it was not representative of the sample. There is variation in healthcare utilisation in this specific triplet in the control community of Chifubu, in the Ndola district, in the Copperbelt province. This is likely in relation to a cholera outbreak in the beginning of 2016 that may have impacted that area more than others, as the Copperbelt has issues with sanitation and clean water. There was a bigger cholera outbreak at the end of 2017/2018. Less variation is seen, but it is possible that the community might have been better prepared learning from the experience of the previous outbreak in 2016 (UNICEF, 2016).

Additionally, the triplets were matched primarily on HIV-related factors, and it was not always possible to closely match on economic variables. A member of the PopART Economists' Team, of which I am a member, has spoken to the qualitative analysts on the PopART team, which has revealed that Triplet 2 is one such case, where the socio-economic status of the control group is greatly improved over the treatment communities (Hayes et al., 2014). All analyses in this chapter exclude Triplet 2, as does the robustness check in Appendix C, which utilises baseline wealth. Summary statistics adjusted to exclude Triplet 2 for baseline wealth, and all other relevant variables used in this chapter, and the following chapter, may be found in Appendix B in Tables 36–40. Figures 13–16 present a pictorial representation of the distribution of the dependent variable, healthcare (HC) utilisation, by community, country, and gender.

Focusing on the upcoming figures, looking at Figure 13, we see significantly higher healthcare utilisation in Zambia than in South Africa, however this is not surprising as Zambia represents a significantly larger make-up of trial participants. Figure 14 provides greater

granularity, as we see a significantly higher usage in Community 1, based in Zambia. Communities 1–12 are located in Zambia, and Communities 13–21 are located in South Africa. This means that with the exception of Community 15, all of the communities with the highest healthcare utilisation are based in Zambia, outside of the one community. Most notable are the outlier communities, 16 and 17, in South Africa, which appear to have very low healthcare utilisation. Figure 15 demonstrates greater female utilisation than that of males, however there is a larger number of female respondents in the trial. Figure 16 shows a more disproportionate gender split in South Africa compared to Zambia, although both favour women in accessing primary healthcare.

**Table 7**  
*Summary Statistics – Total Trial Sample*

|                        | Wave 1 |       |        | Wave 2 |       |        | Wave 3 |       |        | Wave 4 |       |        | Waves 2–4 |       |        |
|------------------------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|-----------|-------|--------|
|                        | Mean   | SD    | N      | Mean   | SD    | N      | Mean   | SD    | N      | Mean   | SD    | N      | Mean      | SD    | N      |
| <b>Total Sample</b>    |        |       |        |        |       |        |        |       |        |        |       |        |           |       |        |
| Final HIV Status       | 0.215  | 0.411 | 37,128 | 0.220  | 0.414 | 27,558 | 0.224  | 0.417 | 27,896 | 0.235  | 0.424 | 26,778 | 0.233     | 0.423 | 35,936 |
| Baseline HIV           | 0.205  | 0.063 | 38,474 | 0.204  | 0.062 | 43,487 | 0.207  | 0.060 | 42,937 | 0.207  | 0.059 | 38,047 | 0.207     | 0.060 | 48,300 |
| Healthcare Utilisation | 0.091  | 0.287 | 7,395  | 0.077  | 0.267 | 5,774  | 0.084  | 0.277 | 5,947  | 0.080  | 0.271 | 5,275  | 0.091     | 0.287 | 14,572 |
| Wealth                 | -0.117 | 1.817 | 37,274 | 0.019  | 1.691 | 29,029 | 0.039  | 1.684 | 29,399 | 0.106  | 1.633 | 27,014 | 0.007     | 1.562 | 36,930 |
| <b>Treated Sample</b>  |        |       |        |        |       |        |        |       |        |        |       |        |           |       |        |
| Final HIV Status       | 0.211  | 0.408 | 25,143 | 0.215  | 0.411 | 18,866 | 0.220  | 0.414 | 18,491 | 0.230  | 0.421 | 17,897 | 0.228     | 0.420 | 23,677 |
| Baseline HIV           | 0.201  | 0.051 | 26,075 | 0.200  | 0.050 | 29,756 | 0.201  | 0.049 | 28,358 | 0.202  | 0.049 | 25,273 | 0.202     | 0.049 | 32,169 |
| Healthcare Utilisation | 0.088  | 0.283 | 4,866  | 0.078  | 0.268 | 3,951  | 0.075  | 0.264 | 3,982  | 0.079  | 0.270 | 3,498  | 0.088     | 0.283 | 9,756  |
| Wealth                 | -0.368 | 1.912 | 25,309 | -0.121 | 1.792 | 19,775 | -0.113 | 1.745 | 19,403 | -0.045 | 1.723 | 18,107 | -0.157    | 1.650 | 24,308 |
| <b>Control Sample</b>  |        |       |        |        |       |        |        |       |        |        |       |        |           |       |        |
| Final HIV Status       | 0.224  | 0.417 | 11,985 | 0.231  | 0.422 | 8,692  | 0.233  | 0.423 | 9,405  | 0.244  | 0.429 | 8,881  | 0.242     | 0.428 | 12,259 |
| Baseline HIV           | 0.213  | 0.082 | 12,399 | 0.213  | 0.080 | 13,731 | 0.217  | 0.076 | 14,579 | 0.216  | 0.075 | 12,774 | 0.217     | 0.077 | 16,131 |
| Healthcare Utilisation | 0.096  | 0.295 | 2,529  | 0.076  | 0.265 | 1,823  | 0.102  | 0.302 | 1,965  | 0.080  | 0.272 | 1,777  | 0.097     | 0.295 | 4,816  |
| Wealth                 | 0.413  | 1.458 | 11,965 | 0.320  | 1.405 | 9,254  | 0.333  | 1.513 | 9,996  | 0.413  | 1.381 | 8,907  | 0.325     | 1.319 | 12,622 |

Wave 1 is baseline data. Waves 2–4 are post-intervention initiation. In the final “Waves 2–4” columns, Final HIV Status and Healthcare Utilisation are counted as 1 if the respondent answered affirmatively in any of the waves, and 0 otherwise. Baseline HIV and Wealth are averaged.

**Table 8**  
*Summary Statistics – Zambia*

|                        | Wave 1 |       |        | Wave 2 |       |        | Wave 3 |       |        | Wave 4 |       |        | Waves 2–4 |       |        |
|------------------------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|-----------|-------|--------|
|                        | Mean   | SD    | N      | Mean   | SD    | N      | Mean   | SD    | N      | Mean   | SD    | N      | Mean      | SD    | N      |
| <b>Total Sample</b>    |        |       |        |        |       |        |        |       |        |        |       |        |           |       |        |
| Final HIV Status       | 0.210  | 0.408 | 19,211 | 0.227  | 0.419 | 15,855 | 0.229  | 0.420 | 16,624 | 0.243  | 0.429 | 16,284 | 0.235     | 0.424 | 21,145 |
| Baseline HIV           | 0.208  | 0.028 | 19,724 | 0.208  | 0.029 | 24,200 | 0.208  | 0.030 | 25,326 | 0.209  | 0.030 | 22,816 | 0.208     | 0.030 | 27,467 |
| Healthcare Utilisation | 0.123  | 0.329 | 3,895  | 0.100  | 0.300 | 3,302  | 0.108  | 0.310 | 3,462  | 0.101  | 0.301 | 3,170  | 0.115     | 0.319 | 8,555  |
| Wealth                 | -0.135 | 1.983 | 19,126 | 0.051  | 1.867 | 16,159 | 0.015  | 1.808 | 17,039 | 0.099  | 1.768 | 16,424 | 0.020     | 1.716 | 21,447 |
| <b>Treated Sample</b>  |        |       |        |        |       |        |        |       |        |        |       |        |           |       |        |
| Final HIV Status       | 0.210  | 0.407 | 12,628 | 0.225  | 0.418 | 10,774 | 0.230  | 0.421 | 10,812 | 0.244  | 0.430 | 10,624 | 0.236     | 0.424 | 13,646 |
| Baseline HIV           | 0.208  | 0.031 | 12,933 | 0.206  | 0.032 | 16,285 | 0.207  | 0.032 | 16,415 | 0.208  | 0.032 | 14,798 | 0.206     | 0.032 | 17,865 |
| Healthcare Utilisation | 0.121  | 0.326 | 2,511  | 0.105  | 0.306 | 2,243  | 0.102  | 0.303 | 2,245  | 0.098  | 0.297 | 2,070  | 0.115     | 0.319 | 5,622  |
| Wealth                 | -0.518 | 2.094 | 12,537 | -0.117 | 1.978 | 10,950 | -0.181 | 1.896 | 10,991 | -0.105 | 1.873 | 10,730 | 2.799     | 1.326 | 13,861 |
| <b>Control Sample</b>  |        |       |        |        |       |        |        |       |        |        |       |        |           |       |        |
| Final HIV Status       | 0.212  | 0.409 | 6,589  | 0.232  | 0.422 | 5,081  | 0.227  | 0.419 | 5,812  | 0.242  | 0.428 | 5,660  | 0.233     | 0.423 | 7,499  |
| Baseline HIV           | 0.209  | 0.021 | 6,791  | 0.211  | 0.023 | 7,915  | 0.212  | 0.024 | 8,911  | 0.212  | 0.024 | 8,018  | 0.212     | 0.024 | 9,602  |
| Healthcare Utilisation | 0.129  | 0.335 | 1,384  | 0.089  | 0.285 | 1,059  | 0.118  | 0.322 | 1,217  | 0.106  | 0.308 | 1,100  | 0.116     | 0.320 | 2,933  |
| Wealth                 | 0.591  | 1.505 | 6,601  | 0.408  | 1.552 | 5,209  | 0.373  | 1.573 | 6,048  | 0.483  | 1.425 | 5,694  | 0.402     | 1.425 | 7,586  |

Wave 1 is baseline data. Waves 2–4 are post-intervention initiation. In the final “Waves 2–4” columns, Final HIV Status and Healthcare Utilisation are counted as 1 if the respondent answered affirmatively in any of the waves, and 0 otherwise. Baseline HIV and Wealth are averaged.

**Table 9**  
*Summary Statistics – South Africa*

|                        | Wave 1 |       |        | Wave 2 |       |        | Wave 3 |       |        | Wave 4 |       |        | Waves 2–4 |       |        |
|------------------------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|-----------|-------|--------|
|                        | Mean   | SD    | N      | Mean   | SD    | N      | Mean   | SD    | N      | Mean   | SD    | N      | Mean      | SD    | N      |
| <b>Total Sample</b>    |        |       |        |        |       |        |        |       |        |        |       |        |           |       |        |
| Final HIV Status       | 0.221  | 0.415 | 18,917 | 0.210  | 0.407 | 11,703 | 0.216  | 0.412 | 11,272 | 0.210  | 0.407 | 7,273  | 0.230     | 0.421 | 14,791 |
| Baseline HIV           | 0.201  | 0.086 | 18,750 | 0.200  | 0.086 | 19,287 | 0.204  | 0.087 | 17,611 | 0.195  | 0.065 | 10,475 | 0.205     | 0.086 | 20,833 |
| Healthcare Utilisation | 0.054  | 0.227 | 3,500  | 0.047  | 0.212 | 2,472  | 0.051  | 0.219 | 2,485  | 0.052  | 0.222 | 1,428  | 0.056     | 0.229 | 6,017  |
| Wealth                 | -0.097 | 1.622 | 18,148 | -0.021 | 1.439 | 12,870 | 0.071  | 1.495 | 12,360 | 0.116  | 1.396 | 10,590 | -0.011    | 1.318 | 15,483 |
| <b>Treated Sample</b>  |        |       |        |        |       |        |        |       |        |        |       |        |           |       |        |
| Final HIV Status       | 0.213  | 0.409 | 12,515 | 0.201  | 0.400 | 8,092  | 0.204  | 0.403 | 7,679  | 0.210  | 0.407 | 7,273  | 0.218     | 0.413 | 10,031 |
| Baseline HIV           | 0.194  | 0.065 | 13,142 | 0.193  | 0.065 | 13,471 | 0.194  | 0.065 | 11,943 | 0.195  | 0.065 | 10,475 | 0.195     | 0.064 | 14,304 |
| Healthcare Utilisation | 0.053  | 0.224 | 2,355  | 0.042  | 0.201 | 1,708  | 0.040  | 0.195 | 1,737  | 0.052  | 0.222 | 1,428  | 0.051     | 0.220 | 4,134  |
| Wealth                 | -0.221 | 1.703 | 12,772 | -0.126 | 1.532 | 8,825  | -0.023 | 1.522 | 8,412  | 0.041  | 1.474 | 7,377  | -0.117    | 1.386 | 10,447 |
| <b>Control Sample</b>  |        |       |        |        |       |        |        |       |        |        |       |        |           |       |        |
| Final HIV Status       | 0.239  | 0.426 | 5,402  | 0.230  | 0.421 | 3,611  | 0.242  | 0.429 | 3,593  | 0.247  | 0.432 | 3,221  | 0.255     | 0.436 | 4,760  |
| Baseline HIV           | 0.218  | 0.120 | 5,608  | 0.216  | 0.120 | 5,816  | 0.224  | 0.117 | 5,668  | 0.222  | 0.119 | 4,756  | 0.225     | 0.117 | 6,529  |
| Healthcare Utilisation | 0.057  | 0.232 | 1,145  | 0.058  | 0.233 | 764    | 0.076  | 0.266 | 748    | 0.038  | 0.192 | 677    | 0.066     | 0.249 | 1,883  |
| Wealth                 | 0.195  | 1.368 | 5,376  | 0.207  | 1.179 | 4,045  | 0.271  | 1.415 | 3,948  | 0.287  | 1.182 | 3,213  | 0.209     | 1.132 | 5,036  |

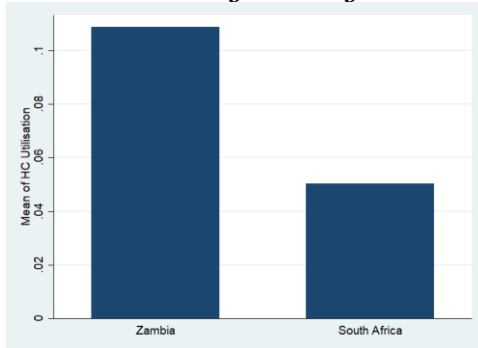
Wave 1 is baseline data. Waves 2–4 are post-intervention initiation. In the final “Waves 2–4” columns, Final HIV Status and Healthcare Utilisation are counted as 1 if the respondent answered affirmatively in any of the waves, and 0 otherwise. Baseline HIV and Wealth are averaged.

**Table 10***Difference in Means T-Tests*

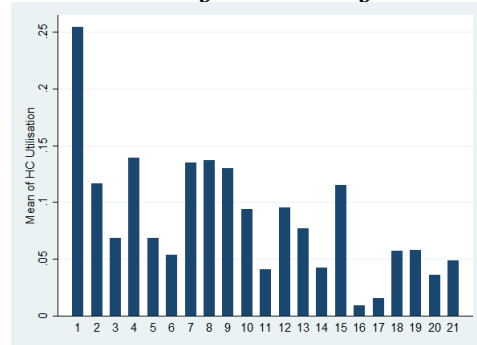
|                        | <b>Intervention</b> |                   |
|------------------------|---------------------|-------------------|
|                        | <b>Pre</b>          | <b>Post</b>       |
| Final HIV Status       | -0.021<br>(0.029)   | -0.022<br>(0.030) |
| Baseline HIV           | -0.015<br>(0.025)   | -0.015<br>(0.025) |
| Healthcare Utilisation | 0.001<br>(0.018)    | 0.016<br>(0.032)  |
| Wealth Index           | -0.153<br>(0.259)   | -0.102<br>(0.203) |
| N                      | 6                   | 6                 |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses, collapsed at triplet level, excluding Triplet 2.

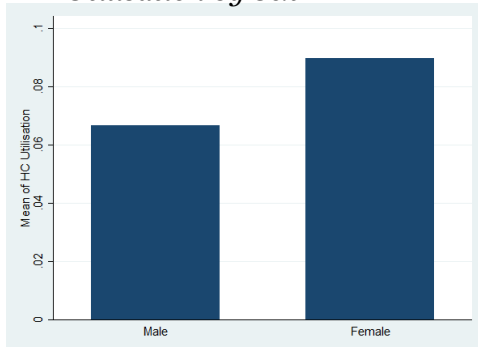
**Figure 13**  
*Utilisation by Country*



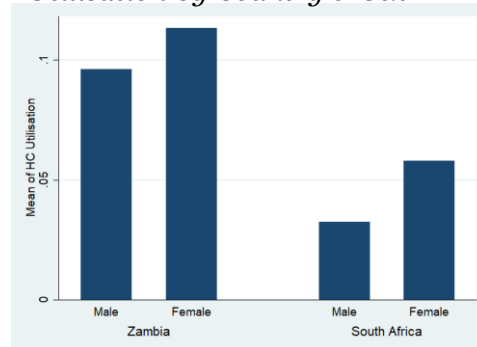
**Figure 14**  
*Utilisation by Community*



**Figure 15**  
*Utilisation by Sex*



**Figure 16**  
*Utilisation by Country & Sex*



Source: Utilisation stands for primary healthcare utilisation.

### 3.4 Methodology

The analysis here presents the main steps used in my investigation of the inequitable distribution of healthcare utilisation. This methodology section outlines the steps needed to estimate the Health Inequity Index (HII), the analysis that is utilised to assess inequity in this chapter, as per Barrenho et al. (2017), Kakwani et al. (1997), O'Donnell et al. (2007), Van Doorslaer et al. (2000), and Wagstaff et al. (1991). These building blocks to formulate the HII analysis include the combination of several well-known inequality analyses, namely: (a) measuring concentration curves, a graphical representation of the inequality in disease burden, characterising inequalities in utilisation and HIV prevalence across different subsamples, estimating treated versus control arms, split by wave. In order to do so, I pool individuals across communities and countries, and rank them by wealth; (b) I measure concentration indices to estimate the magnitude of this inequality; (c) for my penultimate analysis to measure inequity, I measure the distance between the distributions of HIV prevalence and healthcare utilisation to determine the extent of any inequity (measuring the HII); (d) lastly, I describe the t-tests run on the HII results, between the treated and control populations.

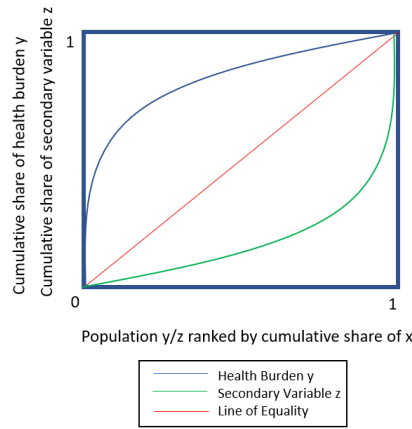
#### 3.4.1 Concentration Curves

This section develops a framework of analysis for concentration curves. Concentration curves are used to examine distributional inequalities in one or two variables of interest, across a population (O'Donnell et al., 2016). The two key variables in a curve include a variable, or variables, of which the distribution is of interest, and a ranking variable, commonly an income measure, against which the distribution is assessed (Kakwani, 1977; Kakwani et al., 1997). To provide a simplistic example, in Figure 17 I present a sample concentration curve. On the y-axis, I show the cumulative share of a health burden (HIV prevalence),  $y$ , and the cumulative share of healthcare utilisation,  $z$ , shown by the blue and green curves, respectively. The distributions of these variables are accounted for by the cumulative proportion of individuals in the population, ranked by a measure of socio-economic status (wealth),  $x$ . In the standard interpretation, wealth is ranked from poorest to richest as you travel along the x-axis.

The living standards measure on the x-axis does not need to have aggregating properties

over the sample population (O'Donnell et al., 2007), it is simply a ranking measure along the x-axis. Typically, ranking variables are normally assumed to be cardinal variables, however O'Donnell et al. (2007) note that making use of an ordinal variable, such as a wealth index, as is the case in this analysis, is also appropriate for the purposes of a ranking variable in health inequality analyses and equity health utilisation analyses (O'Donnell et al., 2007).

**Figure 17**  
*Sample Concentration Curve*



The red line in the diagram is a 45-degree line, representing a line of equality. Along this line everyone, irrespective of their living standards, has the same value of health burden and healthcare utilisation. For example, along the equality line, 20% of the poorest individuals by wealth would be expected to make up 20% of the share of the health burden, or 20% of healthcare utilisation. Alternatively, if the concentration curve lies above the 45-degree line, such as the blue health distribution line does in this example, this implies a pro-poor bias in the health variable. In this case, for example, the 20% poorest individuals would carry more than 20% of the HIV burden. Conversely, a curve lying below the equality line, such as the green line indicating the distribution of healthcare utilisation, implies a pro-rich bias in the health variable (O'Donnell et al., 2007). Here, the 20% poorest make up less than 20% of access to healthcare, hence the pro-rich bias.

To describe the curves more formally, a concentration curve,  $L_h(d_i)$ , represents the share of health need, in this case HIV prevalence, accounted for by a cumulative proportion of the population,  $r_i$ . Replicating this analysis, and choosing a cumulative proportion of a second variable, in this case healthcare utilisation, creates a second concentration curve,  $L_u(d_i)$ , where  $i$  corresponds to the respondent, the individual unit of data in the PopART trial. The

cumulative proportion of HIV prevalence and healthcare utilisation is represented on the y-axis. Then, population  $r_i$  is ranked from poorest to richest by wealth quintile on the x-axis.  $d_i$  represents the cumulative distribution of the y-axis variable, ranked by socio-economic status. In shorthand:

$$L_h(d_i) = C_h \quad (5)$$

$$L_u(d_i) = C_u \quad (6)$$

To calculate the magnitude and significance of deviations away from the line of equality, concentration indices (CIs) are used. I use the methods to describe the inequalities in utilisation across different subsamples, namely treated versus control and split by wave (see Figures 18–24) in the Results section, 3.5. In order to do so, I pool individuals to compute the concentration curves across communities and countries.

### 3.4.2 Concentration Indices

There is a further estimation tool to quantify differences in the inequality of healthcare utilisation: the concentration index (CI). CIs measure inequality in one variable over the distribution of another (Kakwani, 1977). There is a family of concentration indices that have been developed, depending on the properties of variables being tested. For more information, please see Erreygers and Van Ourti (2011). The concentration index quantifies twice the area between the concentration curve and the line of equality, and measures standard errors to test whether the level of inequality is statistically significant. Traditionally, the index takes a negative value when the curve lies above the line of equality, indicating a disproportionate concentration of the HIV burden among the poorer individuals in the population (pro-poor bias) (O'Donnell et al., 2007). Likewise, a positive value for the index curve indicates an inequality, indicating that the health burden falls on the wealthier proportion of the population (pro-rich bias).

In this analysis, the Erreygers index is utilised, which is tailored to bounded variables such as the binary variables *HIV* and *Util* (Erreygers, 2009). The PopART data were gathered by community, at the individual level. In building the concentration indices for health burden and healthcare utilisation, the PopART indices were constructed first at the community level,

by wave. The Erreygers index for *HIV*, in each wave, may be defined as:

$$E(h) = \frac{8}{n^2(b_h - a_h)} \sum_{k=1}^n z_k h_k \quad (7)$$

The Erreygers index for *Util* may be defined as:

$$E(u) = \frac{8}{n^2(b_u - a_u)} \sum_{k=1}^n z_k u_k \quad (8)$$

Where

$$z_k = \frac{n+1}{2} - \gamma_k \quad (9)$$

and  $h$  is the mean HIV prevalence and  $u$  is the mean healthcare utilisation.  $n$  represents the number of individual observations.  $a_h$  and  $b_h$ , and  $a_u$  and  $b_u$ , are the lower and upper bounds for *HIV* and *Util*, respectively. In this case they take on values of 0 and 1, as both variables are binary variables.

$$\sum_{k=1}^n z_k h_k \text{ and } \sum_{k=1}^n z_k u_k$$

expresses the rank-dependence of the indices (Erreygers, 2009). The health and utilisation variables,  $h_k$  and  $u_k$ , of individual  $k$  are weighted by a factor determined by the socio-economic rank,  $\gamma_k$ , of this individual. As defined in Equation 9,  $z_k$  is a function of the number of individual observations,  $n$ , and an individual's socio-economic rank,  $\gamma_k$ . The sign of the weights separates the “rich” from the “poor”. Wealthier individuals with ranks,  $\gamma_k$ , smaller than  $(n+1)/2$  have a positive weight, whilst poorer individuals are those with ranks greater than  $(n+1)/2$ , which is a negative weight (Erreygers, 2009). Tables 11–14 in the Results section present the index results for *HIV* and *Util*, for treated and control populations, separately.

In addition to accommodating bounded variables, the Erreygers index satisfies four

properties that are relevant for this analysis: transferability, mirroring, level independence, and cardinal invariance (Van Doorslaer & Van Ourti, 2012). Transferability follows the concept of an income-related health transfer, where overall social welfare is reduced when the health of a lower-income individual is reduced by the same amount that the health of a higher-income individual is raised (Bleichrodt & Van Doorslaer, 2006; O'Donnell et al., 2016). Mirroring requires the magnitude of measured inequality, as computed in the absolute value of a concentration index, to be independent of whether the index is measuring attainments or shortfalls of the health variable of interest (Erreygers, 2009; O'Donnell et al., 2016). This is of particular relevance for bounded variables so that comparing across populations with different averages does not affect the index value. In this analysis, HIV prevalence, healthcare utilisation, and the wealth index are bounded, and unable to take on negative values, so the mirroring property is of particular relevance. Level independence means that for any given distribution of a variable, if the levels of that variable change by the same absolute (or scalar) amount, the concentration index remains constant, and cardinal invariance implies that a linear transformation of the variable does not alter the index value (Erreygers, 2009). This also fits my data.

To calculate the level of inequity in the analysis, concentration indices are used to calculate the health inequity index.

### 3.4.3 Health Inequity Index

The HII measures the difference between the concentration index for healthcare utilisation and the concentration index for HIV prevalence (Kakwani et al., 1997; O'Donnell et al., 2007). The HII allows us to quantify the comparison of distributions of health need with distributions of healthcare utilisation, across wealth quintiles. Through this analysis, I am able to draw conclusions as to whether the trial had an impact on reducing or increasing any pre-existing inequities, either favouring the poor (pro-poor) or the rich (pro-rich) in healthcare utilisation, factoring in the HIV burden and population wealth (Barrenho et al., 2017).

Van Doorslaer et al. (2000) and Wagstaff et al. (1991) propose the following methodology to calculate inequity, estimating that the magnitude of inequity is twice the size of the area between the two concentration curves. Let  $C_h$  represent the concentration index coefficient for HIV prevalence, and  $C_u$  represent the concentration index coefficient for the healthcare utilisation, and allow notation for the concentration curves to be  $L_h(d_i)$  and  $L_u(d_i)$ . Then, the HII is given by:

$$HII = 2 \int_0^1 [L_u(d_i) - L_h(d_i)] dD = C_u - C_h \quad (10)$$

The HII is bound between  $(-2, 2)$ , with a positive value indicating a pro-rich bias, and a negative value indicating pro-poor inequity. If there is no inequity, the HII takes on a value of 0.

I compute the HIIs at community level. After the calculation of the HII for each community, the data was separated into treated and untreated communities. These communities were then collapsed at the triplet level, so each triplet had a treated and untreated HII value. I conducted a difference of means test between the treated and untreated triplets for each of the indices, in each wave, to test whether there was any significant difference between the two populations, effectively testing to see whether there was any significant change since the initiation of the PopART trial. Additionally, I constructed an “average” of the waves post-initiation of treatment (Waves 2–4). This measure is not a true average, as the binary variables *HIV* and *Util* were measured by counting a “yes” if in any period the respondent answered affirmatively to having HIV, or

utilising primary healthcare. *Wealth* was averaged across the waves.

The following Results section presents my findings of the HII t-tests, as well as the concentration curves, along with the concentration index and HII results.

### 3.5 Results

This section presents the results of the inequality analysis, as shown by the concentration curves and indices (Kakwani, 1977; Kakwani et al., 1997; Wagstaff et al., 1991), and the inequity analysis, as seen in the Health Inequity Index and associated t-tests. Focusing on the concentration curves in Figures 18 and 19, the concentration curves plot out the cumulative HIV burden (blue lines) and healthcare utilisation (red-yellow lines) on the y-axis, against a wealth index for individuals ranked by wealth quintile from lowest to highest, for trial Waves 1–4. Remember that HIV status and the wealth index were asked of all respondents, and healthcare utilisation was answered by a subset of approximately 20% of the total sample. The dashed lines indicate an average of the post-trial initiation of the intervention (Waves 2–4), measured as described in the Data section. As shown by the two graphs, the sample has been split between the treatment and control populations. Looking first at the treatment group, in Figure 18, the blue HIV lines appear above the line of equality, suggesting a pro-poor bias in HIV prevalence. There is not much differentiation between the trial waves, suggesting that the distribution of the HIV burden remains stable.

Although results are not broken down by country, it may be useful to recall differences found in the descriptive data statistics, as discussed in Section 3.3. The post-trial initiation HIV prevalence gap between Zambia and South Africa demonstrated a slightly larger gap between the treatment and control groups in South Africa. The post-trial (Waves 2–4) treatment group in Zambia had a mean HIV prevalence of 23.6%, and the control group had a prevalence of 23.3%. In contrast, in South Africa, the post-trial initiation treatment group had an HIV prevalence rate of 21.8%, and the control group had a prevalence of 25.5%. Ultimately, due to sample size, and the difference in communities, I decided it most accurate to run the analysis with the two countries combined, which is consistent with other relevant PopART literature (Hayes et al., 2019).

Focusing on the distribution of healthcare utilisation, as seen by the red-yellow lines, in both Figure 18 and Figure 19, the curves lie below the line of equality, suggesting a pro-rich bias. This suggests that access to healthcare is disproportionately concentrated within the wealthier proportion of the population. In the Baseline Wave 1, the control group had the greatest distributional inequity, as the red line is located farthest to the right. There is slightly more movement in the curves across the different waves, as can be seen by the

Wave 3 results (orange line), which lies farthest to the right of the other curves. It is possible that this Wave 3 outcome may be a result of a delayed demand change in response to the WHO change of protocol in Wave 2, moving to immediate ART initiation upon diagnosis. Ultimately, a mathematical analysis of the indices, as described in the Methodology section, is necessary to determine any significance between treatment and control groups, across waves.

The difference in the treatment and control groups, by wave, may be seen in Figures 20–24. Again there is a picture of a close distribution of HIV prevalence, and a more disparate distribution of healthcare utilisation, between the treatment and control groups. As can be seen in Figure 19, in Wave 3 (Figure 22), the curves are farthest away from the line of equality, suggesting the largest inequality in healthcare utilisation; however, further testing is needed to check for statistical significance. In all waves (Figures 20–24) there is a separation between the distributions of treatment and control groups.

In order to estimate the magnitude of the inequalities in distributions, concentration indices were measured. Focusing on the concentration indices, Tables 11 and 12 present the index results by wave, for the treatment and control communities, laid out by triplet. I see almost unanimously negative index results, indicating a pro-poor inequity in the distribution of health need, as proxied by HIV, significant most generally at the 1% level. Conversely, when looking at the concentration index values for healthcare utilisation, in Tables 13 and 14, I see positive, significant coefficients, indicating a pro-rich equity in healthcare utilisation. The coefficients are generally higher in the healthcare utilisation index than in the health need index, suggesting that the level of inequity in the distribution of healthcare utilisation is greater than the level of inequity in the distribution of health need, which is measured in this case by HIV prevalence. These index values support the visual evidence of the concentration curves, which show that the distribution of HIV prevalence lies above the line of equality, suggesting a pro-poor distribution, and that the distribution of healthcare utilisation lies farther towards the lower-right quadrant, meaning it takes on a more pro-rich inequality.

To determine the magnitude of horizontal inequity, the Health Inequity Index on healthcare utilisation was calculated based on the concentration index results. Tables 15 and 16 present the health inequity indices (HII values) and significance levels, by community, triplet, and wave, for the treated and control populations. Both treated and

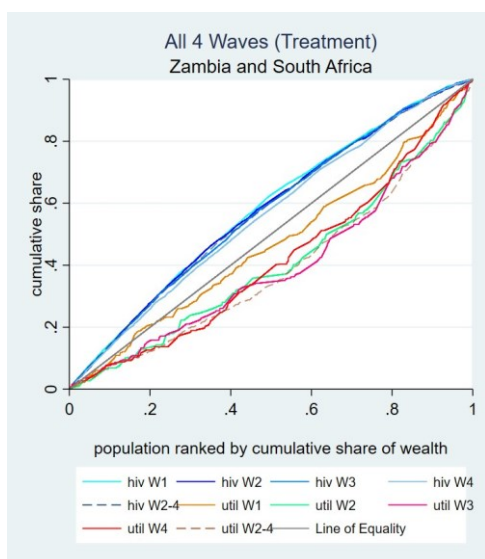
control populations indicate almost exclusively positive index values, indicating a very pro-rich inequity in healthcare utilisation, as ranked by wealth. The overwhelming pro-rich results are supported by the evidence as viewed earlier in the concentration curves and indices.

As laid out in Section 3.4, the Health Inequity Index was built at the community level and collapsed at the triplet level. Difference in means t-tests were run on these six clusters, presented in Table 17, and show that there is a meaningful difference in the final Wave 4 of the trial in the health inequity index, when testing the difference in mean HII value between the treated and control populations, at the triplet level. Specifically, the test indicates that the impact of the PopART trial on healthcare utilisation was to increase the level of pro-rich inequity in the population, in the fourth wave, significant at the 5% level. This is demonstrated in Table 17, as seen by the HII mean difference of 0.072 ( $p < 0.05$ ). This significant difference is the impact of the PopART trial. I note that it is a limitation of this analysis that the significance found is at the end of the trial, and further measurements after the end of the trial would be needed to establish any enduring effects.

To confirm that this difference in utilisation is solely a result of the trial, and there are no confounding factors such as a changing wealth distribution by wave, I conducted a robustness test of the analysis. In this analysis I ranked by the baseline (Wave 1) wealth index and maintained this same wealth index for ranking across all waves. As per the reasons noted earlier, including running Friedman tests per wave, I consider this robustness check to be a less accurate measure of the findings, as wealth is not allowed to vary by wave, along with HIV and utilisation outcomes. This is in contrast to the main analysis in this chapter, which allows the wealth index to vary by wave. The results of the robustness check support my analysis. All concentration curves, concentration indices, and HII values and difference of means tests may be found in the Appendix in supporting Figures 32–39, and Tables 51–57. The robustness analysis finds a positive, significant increase in pro-poor inequity in the third wave of the trial. These results also reveal significant findings near the end of the trial, as do the results of this chapter. Again, it is noted that it is a limitation that at this time there are no further data available past the fourth wave of the trial to test whether these end-of-trial movements in healthcare utilisation are temporary or lasting.

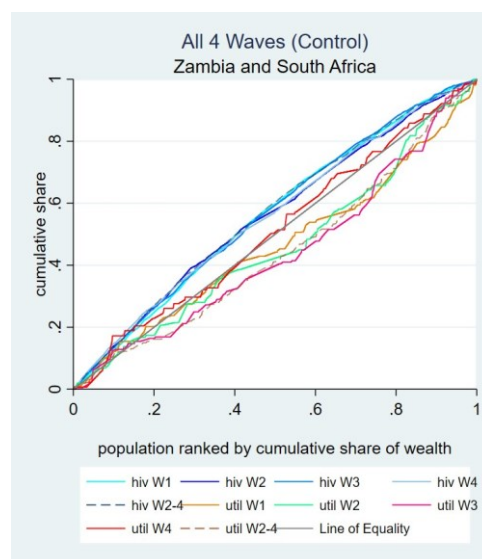
**Figure 18**

*Concentration Curves – Treated*



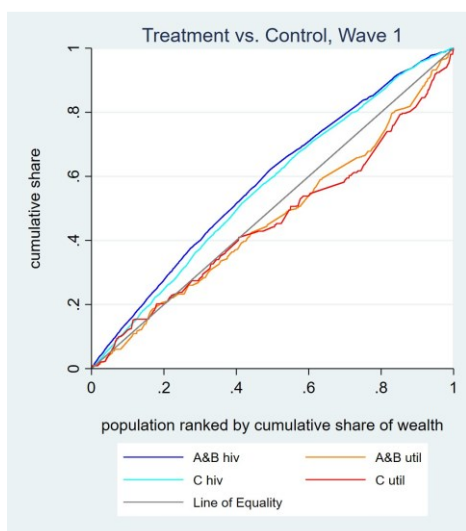
**Figure 19**

*Concentration Curves – Control*



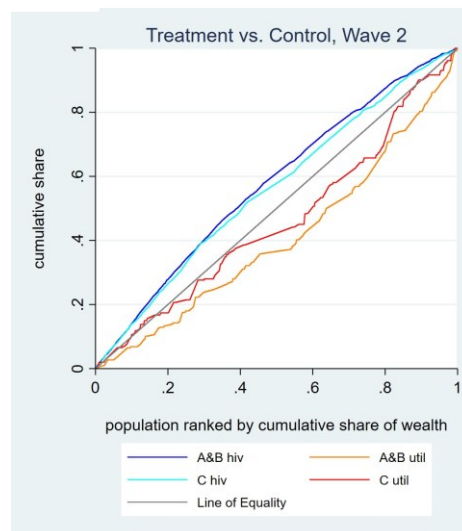
**Figure 20**

*Concentration Curves – Wave 1*



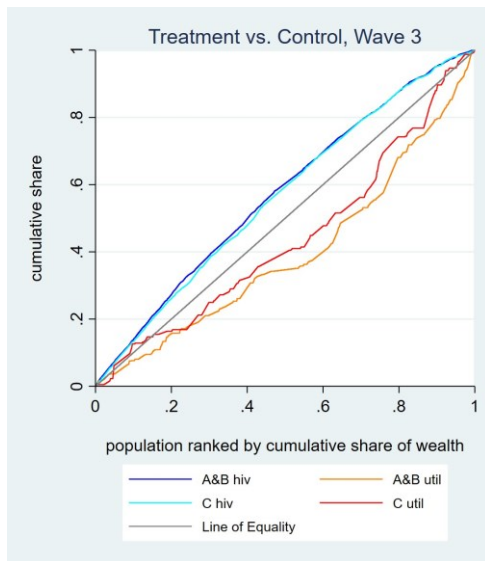
**Figure 21**

*Concentration Curves – Wave 2*



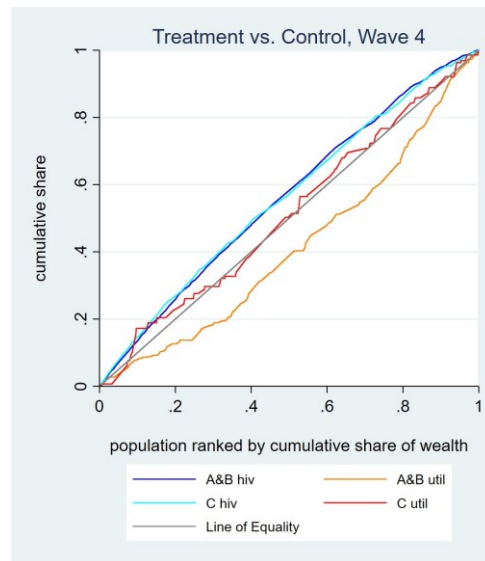
**Figure 22**

*Concentration Curves – Wave 3*



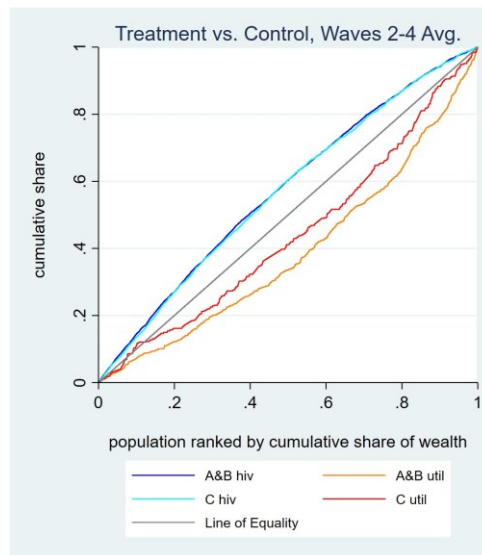
**Figure 23**

*Concentration Curves – Wave 4*



**Figure 24**

*Concentration Curves – Avg.*



**Table 11***HIV Prevalence Concentration Index by Wave – Treated*

|                     | (W1)      | (W2)      | (W3)      | (W4)      | (W2–4)    |
|---------------------|-----------|-----------|-----------|-----------|-----------|
| <b>Zambia</b>       |           |           |           |           |           |
| <b>Triplet 1</b>    | -0.095*** | -0.108*** | -0.105*** | -0.095*** | -0.107*** |
| Community 1         | (0.026)   | (0.022)   | (0.024)   | (0.025)   | (0.023)   |
|                     | [972]     | [1,527]   | [1,214]   | [1,268]   | [1,622]   |
| Community 2         | -0.074*** | -0.064*** | -0.076*** | -0.112*** | -0.078*** |
|                     | (0.025)   | (0.023)   | (0.026)   | (0.027)   | (0.026)   |
|                     | [1,002]   | [1,188]   | [1,007]   | [1,176]   | [1,297]   |
| <b>Triplet 3</b>    | -0.061*** | -0.101*** | -0.106*** | -0.137*** | -0.119*** |
| Community 8         | (0.020)   | (0.026)   | (0.025)   | (0.028)   | (0.024)   |
|                     | [1,570]   | [1,182]   | [1,393]   | [1,282]   | [1,771]   |
| Community 9         | -0.091*** | -0.041    | -0.066**  | -0.062**  | -0.064**  |
|                     | (0.024)   | (0.026)   | (0.030)   | (0.031)   | (0.028)   |
|                     | [1,372]   | [1,253]   | [1,043]   | [1,043]   | [1,432]   |
| <b>Triplet 4</b>    | -0.073*** | -0.118*** | -0.084*** | -0.090*** | -0.115*** |
| Community 10        | (0.021)   | (0.025)   | (0.024)   | (0.025)   | (0.024)   |
|                     | [1,741]   | [1,579]   | [1,831]   | [1,703]   | [2,194]   |
| Community 11        | -0.064*** | -0.064**  | -0.081*** | -0.059*   | -0.064**  |
|                     | (0.024)   | (0.029)   | (0.029)   | (0.033)   | (0.029)   |
|                     | [1,345]   | [1,134]   | [1,183]   | [1,112]   | [1,453]   |
| <b>South Africa</b> |           |           |           |           |           |
| <b>Triplet 5</b>    | -0.072*** | -0.044    | -0.041    | -0.050*   | -0.059**  |
| Community 13        | (0.022)   | (0.028)   | (0.031)   | (0.030)   | (0.029)   |
|                     | [2,287]   | [1,386]   | [1,195]   | [1,133]   | [1,644]   |
| Community 14        | -0.086*** | -0.089*** | -0.097*** | -0.016    | -0.080*** |
|                     | (0.020)   | (0.031)   | (0.028)   | (0.030)   | (0.027)   |
|                     | [2,084]   | [1,187]   | [1,241]   | [1,105]   | [1,645]   |
| <b>Triplet 6</b>    | -0.092*** | -0.054*** | -0.070*** | -0.075*** | -0.101*** |
| Community 16        | (0.023)   | (0.018)   | (0.025)   | (0.028)   | (0.025)   |
|                     | [1,986]   | [1,209]   | [1,471]   | [1,367]   | [1,951]   |
| Community 18        | -0.107*** | -0.104*** | -0.109*** | -0.030    | -0.109*** |
|                     | (0.019)   | (0.024)   | (0.024)   | (0.024)   | (0.024)   |
|                     | [2,264]   | [1,270]   | [1,127]   | [1,187]   | [1,499]   |
| <b>Triplet 7</b>    | -0.136*** | -0.122*** | -0.135*** | -0.123*** | -0.181*** |
| Community 19        | (0.016)   | (0.016)   | (0.019)   | (0.019)   | (0.019)   |
|                     | [1,654]   | [1,395]   | [1,204]   | [1,121]   | [1,541]   |
| Community 20        | -0.142*** | -0.087*** | -0.079*** | -0.077*** | -0.121*** |
|                     | (0.014)   | (0.016)   | (0.016)   | (0.017)   | (0.019)   |
|                     | [1,943]   | [1,436]   | [1,309]   | [1,224]   | [1,574]   |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses. Observation count in brackets.

**Table 12***HIV Prevalence Concentration Index by Wave – Control*

|                     | (W1)      | (W2)      | (W3)      | (W4)      | (W2–4)    |
|---------------------|-----------|-----------|-----------|-----------|-----------|
| <b>Zambia</b>       |           |           |           |           |           |
| <b>Triplet 1</b>    | -0.063*** | -0.031    | -0.043    | -0.061**  | -0.068*** |
| Community 3         | (0.022)   | (0.024)   | (0.027)   | (0.027)   | (0.026)   |
|                     | [1,761]   | [1,456]   | [1,205]   | [1,205]   | [1,584]   |
| <b>Triplet 3</b>    | -0.069*** | -0.106*** | -0.084*** | -0.073**  | -0.101*** |
| Community 7         | (0.018)   | (0.030)   | (0.024)   | (0.028)   | (0.023)   |
|                     | [2,090]   | [927]     | [1,402]   | [1,277]   | [1,880]   |
| <b>Triplet 4</b>    | -0.119*** | -0.129*** | -0.133*** | -0.159*** | -0.164*** |
| Community 12        | (0.032)   | (0.029)   | (0.025)   | (0.027)   | (0.026)   |
|                     | [1,032]   | [1,250]   | [1,536]   | [1,436]   | [1,818]   |
| <b>South Africa</b> |           |           |           |           |           |
| <b>Triplet 5</b>    | -0.128*** | -0.166*** | -0.131*** | -0.165*** | -0.177*** |
| Community 15        | (0.023)   | (0.030)   | (0.031)   | (0.036)   | (0.028)   |
|                     | [1,826]   | [1,152]   | [1,035]   | [919]     | [1,523]   |
| <b>Triplet 6</b>    | -0.039*   | -0.010    | -0.022    | -0.067**  | -0.048*   |
| Community 17        | (0.023)   | (0.034)   | (0.029)   | (0.032)   | (0.028)   |
|                     | [1,928]   | [1,096]   | [1,370]   | [1,189]   | [1,794]   |
| <b>Triplet 7</b>    | -0.026*** | -0.035*** | -0.028**  | -0.025*   | -0.047*** |
| Community 21        | (0.010)   | (0.012)   | (0.011)   | (0.013)   | (0.015)   |
|                     | [1,473]   | [1,210]   | [1,127]   | [1,038]   | [1,339]   |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses. Observation count in brackets.

**Table 13***Healthcare Utilisation Concentration Index by Wave – Treated*

|                     | (W1)     | (W2)     | (W3)     | (W4)     | (W2–4)   |
|---------------------|----------|----------|----------|----------|----------|
| <b>Zambia</b>       |          |          |          |          |          |
| <b>Triplet 1</b>    | 0.094    | 0.022    | 0.020    | 0.034    | 0.069*   |
| Community 1         | (0.070)  | (0.051)  | (0.064)  | (0.054)  | (0.040)  |
|                     | [198]    | [336]    | [246]    | [259]    | [706]    |
| Community 2         | -0.053   | 0.053    | 0.028    | 0.049    | 0.042    |
|                     | (0.052)  | (0.039)  | (0.047)  | (0.050)  | (0.035)  |
|                     | [224]    | [243]    | [215]    | [185]    | [540]    |
| <b>Triplet 3</b>    | 0.092    | 0.151    | 0.231*** | 0.127    | 0.0367   |
| Community 8         | (0.087)  | (0.093)  | (0.085)  | (0.091)  | (0.054)  |
|                     | [284]    | [244]    | [281]    | [247]    | [689]    |
| Community 9         | 0.074    | 0.263**  | 0.240*   | 0.314**  | 0.152**  |
|                     | (0.070)  | (0.109)  | (0.126)  | (0.130)  | (0.073)  |
|                     | [273]    | [240]    | [199]    | [193]    | [537]    |
| <b>Triplet 4</b>    | 0.297*** | 0.361*** | 0.135    | 0.153    | 0.158**  |
| Community 10        | (0.073)  | (0.115)  | (0.115)  | (0.103)  | (0.066)  |
|                     | [339]    | [315]    | [383]    | [317]    | [887]    |
| Community 11        | 0.222    | 0.491**  | 0.349**  | -0.103   | 0.277**  |
|                     | (0.137)  | (0.192)  | (0.173)  | (0.425)  | (0.129)  |
|                     | [218]    | [219]    | [261]    | [223]    | [601]    |
| <b>South Africa</b> |          |          |          |          |          |
| <b>Triplet 5</b>    | 0.457*** | 0.277*** | 0.202    | 0.186    | 0.091    |
| Community 13        | (0.091)  | (0.091)  | (0.125)  | (0.158)  | (0.070)  |
|                     | [466]    | [341]    | [296]    | [251]    | [747]    |
| Community 14        | 0.250*** | 0.180    | 0.303    | 0.452*   | 0.186    |
|                     | (0.094)  | (0.240)  | (0.343)  | (0.262)  | (0.161)  |
|                     | [340]    | [260]    | [279]    | [211]    | [640]    |
| <b>Triplet 6</b>    | 0.212    | 0.000    | 0.217    | 0.268    | 0.142    |
| Community 16        | (0.338)  | (0.000)  | (0.259)  | (0.291)  | (0.196)  |
|                     | [406]    | [221]    | [335]    | [291]    | [738]    |
| Community 18        | 0.355*** | 0.245    | 0.255    | 0.336*** | 0.129    |
|                     | (0.131)  | (0.191)  | (0.237)  | (0.093)  | (0.088)  |
|                     | [422]    | [254]    | [243]    | [232]    | [612]    |
| <b>Triplet 7</b>    | 0.266**  | 0.265*   | 0.497*** | 0.534*** | 0.332*** |
| Community 19        | (0.119)  | (0.151)  | (0.138)  | (0.141)  | (0.086)  |
|                     | [358]    | [298]    | [269]    | [228]    | [672]    |
| Community 20        | 0.097    | 0.100    | 0.201    | 0.243    | 0.008    |
|                     | (0.173)  | (0.211)  | (0.129)  | (0.294)  | (0.110)  |
|                     | [344]    | [302]    | [291]    | [198]    | [664]    |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses. Observation count in brackets.

**Table 14***Healthcare Utilisation Concentration Index by Wave – Control*

|                     | (W1)    | (W2)    | (W3)    | (W4)    | (W2–4)   |
|---------------------|---------|---------|---------|---------|----------|
| <b>Zambia</b>       |         |         |         |         |          |
| <b>Triplet 1</b>    | 0.097** | -0.006  | 0.011   | 0.003   | 0.010    |
| Community 3         | (0.042) | (0.034) | (0.027) | (0.016) | (0.021)  |
|                     | [363]   | [286]   | [231]   | [241]   | [647]    |
| <b>Triplet 3</b>    | 0.040   | 0.088   | 0.070   | -0.041  | 0.039    |
| Community 7         | (0.037) | (0.060) | (0.045) | (0.040) | (0.032)  |
|                     | [455]   | [210]   | [289]   | [240]   | [663]    |
| <b>Triplet 4</b>    | -0.038  | 0.022   | 0.079** | 0.067*  | 0.065*** |
| Community 12        | (0.061) | (0.034) | (0.033) | (0.038) | (0.025)  |
|                     | [219]   | [277]   | [311]   | [248]   | [721]    |
| <b>South Africa</b> |         |         |         |         |          |
| <b>Triplet 5</b>    | -0.042  | -0.100* | -0.041  | -0.035  | -0.041   |
| Community 15        | (0.035) | (0.056) | (0.056) | (0.038) | (0.035)  |
|                     | [376]   | [256]   | [221]   | [210]   | [606]    |
| <b>Triplet 6</b>    | -0.006  | 0.003   | 0.028   | -0.013  | 0.013    |
| Community 17        | (0.015) | (0.010) | (0.025) | (0.013) | (0.013)  |
|                     | [412]   | [277]   | [278]   | [253]   | [696]    |
| <b>Triplet 7</b>    | -0.008  | -0.038* | 0.019   | -0.051  | -0.026   |
| Community 21        | (0.027) | (0.022) | (0.036) | (0.036) | (0.027)  |
|                     | [352]   | [222]   | [237]   | [199]   | [550]    |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses. Observation count in brackets.

**Table 15**  
*Health Inequity Index by Wave – Treated*

|                     | (W1)     | (W2)     | (W3)    | (W4)     | (W2-4)   |
|---------------------|----------|----------|---------|----------|----------|
| <b>Zambia</b>       |          |          |         |          |          |
| <b>Triplet 1</b>    | 0.178**  | 0.202*** | 0.172** | 0.148*   | 0.244*** |
| Community 1         | (0.082)  | (0.066)  | (0.079) | (0.083)  | (0.053)  |
|                     | [193]    | [313]    | [237]   | [250]    | [687]    |
| Community 2         | -0.005   | 0.024    | 0.140*  | 0.259*** | 0.120**  |
|                     | (0.076)  | (0.067)  | (0.076) | (0.077)  | (0.055)  |
|                     | [216]    | [227]    | [207]   | [176]    | [520]    |
| <b>Triplet 3</b>    | 0.018    | -0.021   | 0.040   | 0.181**  | 0.060    |
| Community 8         | (0.057)  | (0.075)  | (0.075) | (0.075)  | (0.050)  |
|                     | [280]    | [234]    | [272]   | [240]    | [679]    |
| Community 9         | -0.076   | 0.095    | -0.051  | 0.030    | 0.086    |
|                     | (0.071)  | (0.073)  | (0.083) | (0.093)  | (0.057)  |
|                     | [269]    | [238]    | [197]   | [190]    | [531]    |
| <b>Triplet 4</b>    | 0.235*** | 0.103    | 0.097   | 0.204*** | 0.187*** |
| Community 10        | (0.061)  | (0.063)  | (0.059) | (0.067)  | (0.045)  |
|                     | [337]    | [305]    | [381]   | [215]    | [879]    |
| Community 11        | 0.019    | 0.167**  | 0.125*  | 0.074    | 0.158*** |
|                     | (0.073)  | (0.076)  | (0.067) | (0.078)  | (0.051)  |
|                     | [215]    | [211]    | [258]   | [221]    | [593]    |
| <b>South Africa</b> |          |          |         |          |          |
| <b>Triplet 5</b>    | 0.126**  | 0.023    | 0.080   | -0.006   | 0.074    |
| Community 13        | (0.057)  | (0.067)  | (0.077) | (0.074)  | (0.052)  |
|                     | [428]    | [269]    | [250]   | [240]    | [691]    |
| Community 14        | 0.022    | 0.052    | 0.138** | 0.169**  | 0.122*** |
|                     | (0.054)  | (0.069)  | (0.061) | (0.073)  | (0.046)  |
|                     | [335]    | [236]    | [253]   | [203]    | [615]    |
| <b>Triplet 6</b>    | 0.197*** | 0.102**  | 0.087   | 0.029    | 0.135*** |
| Community 16        | (0.053)  | (0.045)  | (0.058) | (0.065)  | (0.044)  |
|                     | [372]    | [193]    | [284]   | [282]    | [703]    |
| Community 18        | 0.139*** | 0.123**  | 0.065   | 0.143*   | 0.086*   |
|                     | (0.049)  | (0.055)  | (0.057) | (0.073)  | (0.044)  |
|                     | [414]    | [243]    | [224]   | [227]    | [605]    |
| <b>Triplet 7</b>    | 0.139*** | 0.082*   | 0.122** | 0.264*** | 0.204*** |
| Community 19        | (0.044)  | (0.046)  | (0.048) | (0.063)  | (0.040)  |
|                     | [345]    | [280]    | [250]   | [227]    | [656]    |
| Community 20        | 0.131*** | 0.056    | 0.100** | 0.072    | 0.069*   |
|                     | (0.039)  | (0.043)  | (0.048) | (0.048)  | (0.038)  |
|                     | [338]    | [280]    | [260]   | [194]    | [644]    |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses. Observation count in brackets.

**Table 16**  
*Health Inequity Index by Wave – Control*

|                     | (W1)     | (W2)     | (W3)     | (W4)    | (W2–4)   |
|---------------------|----------|----------|----------|---------|----------|
| <b>Zambia</b>       |          |          |          |         |          |
| <b>Triplet 1</b>    | 0.180*** | 0.065    | -0.051   | 0.066   | 0.011    |
| Community 3         | (0.068)  | (0.064)  | (0.069)  | (0.063) | (0.047)  |
|                     | [357]    | [277]    | [227]    | [237]   | [638]    |
| <b>Triplet 3</b>    | 0.048    | 0.263*** | 0.130*   | 0.041   | 0.153*** |
| Community 7         | (0.053)  | (0.084)  | (0.070)  | (0.077) | (0.050)  |
|                     | [437]    | [181]    | [272]    | [237]   | [637]    |
| <b>Triplet 4</b>    | 0.056    | 0.177**  | 0.278*** | 0.103   | 0.236*** |
| Community 12        | (0.083)  | (0.071)  | (0.065)  | (0.075) | (0.048)  |
|                     | [213]    | [265]    | [305]    | [241]   | [704]    |
| <b>South Africa</b> |          |          |          |         |          |
| <b>Triplet 5</b>    | 0.010    | 0.055    | 0.024    | 0.123   | 0.153*** |
| Community 15        | (0.061)  | (0.086)  | (0.093)  | (0.083) | (0.058)  |
|                     | [367]    | [212]    | [190]    | [201]   | [572]    |
| <b>Triplet 6</b>    | 0.030    | 0.060    | 0.006    | -0.049  | 0.031    |
| Community 17        | (0.052)  | (0.073)  | (0.072)  | (0.072) | (0.048)  |
|                     | [402]    | [227]    | [239]    | [242]   | [648]    |
| <b>Triplet 7</b>    | -0.009   | -0.043   | 0.040    | -0.030  | 0.014    |
| Community 21        | (0.030)  | (0.032)  | (0.041)  | (0.037) | (0.033)  |
|                     | [335]    | [197]    | [218]    | [197]   | [534]    |

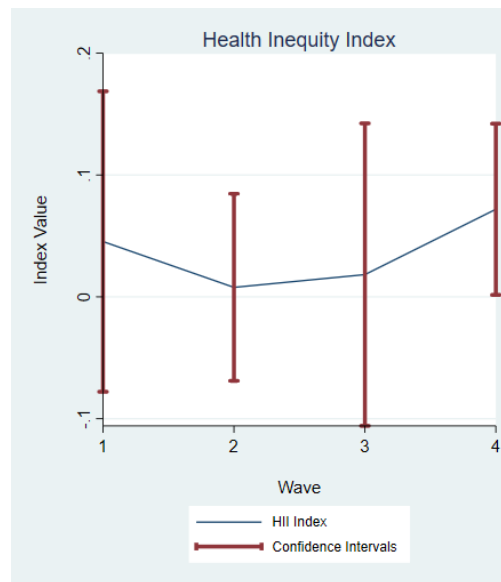
Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses. Observation count in brackets.

**Table 17**

Difference in Means T-Tests by Wave

|                        | (W1)              | (W2)              | (W3)              | (W4)                             | (W2-4)           |
|------------------------|-------------------|-------------------|-------------------|----------------------------------|------------------|
| HII                    | 0.045<br>(0.048)  | 0.008<br>(0.030)  | 0.018<br>(0.048)  | <b>0.072**</b><br><b>(0.027)</b> | 0.022<br>(0.037) |
| CI, Health Need        | -0.020<br>(0.027) | -0.007<br>(0.026) | -0.010<br>(0.023) | 0.006<br>(0.026)                 | 0.002<br>(0.028) |
| CI, Health Utilisation | -0.010<br>(0.031) | 0.017<br>(0.018)  | -0.009<br>(0.014) | 0.018<br>(0.019)                 | 0.007<br>(0.015) |
| N                      | 6                 | 6                 | 6                 | 6                                | 6                |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses, collapsed at triplet level.

**Figure 25***Health Inequity Index Confidence Intervals*

Note: Tests for difference in means between treated and control populations.

### 3.6 Discussion

The PopART intervention is designed to analyse the impact of universal counselling and testing, providing linkage to care, and early ART initiation when appropriate, at the household level on HIV incidence (HPTN HIV Prevention Trials Network, 2021). In this study, I have examined an additional impact of this research, using the PopART data to analyse the impact of the trial on horizontal inequities in healthcare utilisation in Zambia and South Africa. The results indicate an initial insignificant, pro-rich bias in the study population in healthcare utilisation, and that a significant furthering of this inequity is indicated at the end of the trial. Further testing must be conducted to see whether this change is of a temporary or permanent nature. I conducted my analysis using concentration indices and the Health Inequity Index, measured in each of the four waves of the trial, and also averaged for the latter three waves of the trial once treatment was initiated. In the last wave of the trial, a significant, positive pro-rich increase is seen.

There is always the risk that an intervention may exacerbate an underlying inequity. After conducting this analysis, I propose a need for the reporting of any pre-existing, estimated inequities to be included in the RCT design. For example, with the PopART trial, just as triplets were matched on geographical area, implementing partners for HIV service provision, and HIV prevalence, in an effort to minimise between-community variance in baseline HIV incidence (Hayes et al., 2014), an inequity analysis could have been implemented on service provision to support the matching efforts. Furthermore, inequity analyses would fall under items 3a, Trial Design, in the CONSORT guidelines for RCT, should they be included in the way I have just described. Or, they might be included under Section 20, Trial Limitations (CONSORT; Consolidated Standards of Reporting Trials).

As previously discussed, research has suggested that reasons such as stigma or fundamental issues in infrastructure may act as barriers to treatment reaching the lower socio-economic classes (Hargreaves et al., 2016; Orach & Garimoi, 2009; Parker & Aggleton, 2003; Van Doorslaer & Wagstaff, 1992; Wagstaff, 2000). Policies directed at these problems may help alleviate such burdens. Additionally, the PopART trial is an intervention that reaches people in their homes, perhaps limiting the need for additional access to primary healthcare. This effect may differ across socio-economic groups. In the PopART trial specifically, HIV is

concentrated among the poorer. This may suggest a reason for wealthier households to utilise a greater amount of primary healthcare, as services are not being provided in their own home.

There are several limitations to the analysis. It is important to remember that in this study, as a step towards measuring inequity, inequalities are measured against a line of equity, where the distribution of healthcare utilisation is proportional to that of HIV prevalence. However, this is a subjective assumption. It is possible in these populations that there are other needs for healthcare that are disproportionate to the health burden. Ideally, of course, health needs are met. My analysis is limited in its scope as it focuses on one particular disease burden. Given that almost 50,000 individuals participated in the trial, it is unfortunate that I am not able to run the analysis at the individual level, as the communities were placed into clusters based on baseline community HIV status. The healthcare variable used in this analysis is limited in scope as I do not know whether the individual sought care for HIV, specifically, and also because the question was posed to only a subset of the population cohort. As international guidelines changed mid-trial, I was only able to measure two arms of the trial, not three, and did not have enough data to produce a comparative analysis of the two countries.

A further limitation is a potential downward bias on HIV prevalence in the data. The 20% of the sample who were queried on healthcare utilisation were a random sample. Thus, there would be no reason to expect that HIV prevalence would be dissimilar to the overall sample. As depicted in Table 7, for the 20% sample, in Waves 1–4, HIV prevalence rates in the total sample were 21.5%, 22.0%, 22.4%, and 23.5%. If one were to look at the total sample, the HIV prevalence rates are 21.5%, 30.4%, 33.0%, and 34.9%, a clearly higher level of prevalence. However, the analysis in this chapter only made use of individuals from the 20% that self-selected into answering the questions on healthcare utilisation. This may introduce a bias toward individuals more likely to utilise health services, be more conservative or cautious in their behaviours, or perhaps comprise a lower risk group of individuals, compared to the 25.73% of the individuals who were offered the chance to answer the questions and declined to answer. I have assessed the prevalence numbers based on all individuals who were offered the survey, and indeed, the prevalence is significantly more in line with the total sample (21.0%, 30.9%, 29.7%, and 29.9% for Waves 1–4, respectively), indicating that the bias theory holds merit in terms of which individuals

chose to answer the question. With a lower-than-normal prevalence rate, this could slightly overstate the pro-rich finding.

A further consideration of the analysis is that the healthcare utilisation outcome is measured in all study participants and is not limited to those infected with HIV. Healthcare utilisation includes all forms of outpatient medical care, not just HIV-related ones. Under the existing standard of care in Zambia and South Africa, PLHIV may visit outpatient clinics at hospitals, or community-based clinics for viral load testing and ART refills (Damulak et al., 2021; Hoffman et al., 2021; Msimango et al., 2020). Thus, the CHiPs programme could have displaced some outpatient visits from PLHIV, moving them outside of the capture of the healthcare utilisation variable, and into community clinics, which I am not able to quantify in this analysis. This could, in turn, have created more availability in outpatient clinics for uninfected individuals. I did not limit the analysis to PLHIV for this reason – the trial should have had benefits for all individuals in the impacted communities, PLHIV and HIV-negative alike. However, it is fair to note that this could create a bias in the analysis. There could potentially be fewer HIV-infected individuals captured in the inequity analysis. As a positive HIV status is correlated with a lower socio-economic status, this could then potentially overstate the pro-rich bias.

Furthermore, one limitation regarding the CHiPs activity could have been a lack of clarity on whether any uptake of VMMC would be captured in the utilisation variable. Unfortunately, I do not have this data. However, as the results of the analysis are split between the control and the treatment groups, the level of utilisation for the treatment group offered VMMC is already captured in the analysis. Although I do not have the data on which individuals in the trial opted to be circumcised during the course of the trial, it is known that VMMC is associated with a decrease in sexually transmitted infections, so it is possible that those that pursued VMMC as a result of the trial had a reduced need for outside healthcare services.

In conclusion, this chapter has provided evidence that the PopART trial widened a pro-rich inequity in healthcare utilisation. These results suggest a need for policy improvements aimed at reaching the lower socio-economic population, possibly focused on stigma, although more work would need to be done in this area. This chapter has demonstrated that there is much more research that can be done, focused on both HIV and on low-income country health in general, using the methods laid out in the chapter. Nevertheless, given the limited work on inequities in low-income countries, and the complete absence of

work on inequities in RCT interventions in low-income countries, specifically on HIV, the findings of this chapter are important and may be used to inform future trial design. Given the high prevalence of HIV in the low-income households of Zambia and South Africa, these results strengthen the case for interventions tailored to bringing information to poorer households about the benefits of prevention and aftercare.

## **4 Impacts of PopART (HPTN 071) on Health-Related Quality of Life: Roles of Sex, Wealth, Education, and Employment**

### **4.1 Introduction**

In this chapter I assess the impact of a universal test and treat intervention for HIV on the health-related quality of life in Zambia and South Africa, and the extent to which it varies across sex, wealth, education, and employment status. Whilst HIV has historically been a cause of premature mortality and morbidity, with the availability of antiretroviral therapy, it has in many geographies now transitioned into a chronic disease, with the focus of interventions shifting towards disease management (Basavaraj et al., 2010; Kharsany & Karim, 2016) and the improvement of health-related quality of life. For example, two identical ongoing trials, one in SSA and another in the US and South America (HVTN 805/HPTN 093, 2022), focus on the impact of short-term breaks in treatment, known as “analytical treatment interruptions” (ATIs) in ART, and their impact on the health and well-being of PLHIV. These trials are in response to the reality that patients may at times need to interrupt their ART due to, for example, family duties, illness, or even unbearable ART side effects. There have also been a number of interventions aimed at improving the focus of care on psychosocial interventions to raise HRQoL (Lutgendorf et al., 1994), such as cognitive-behavioural interventions (Bhatta et al., 2017; Eller, 1999; Lechner et al., 2003), technology oriented interventions (Cho et al., 2017), and, more recently, a focus on reducing stigma (Andersson et al., 2020; Herrmann et al., 2013; Slater et al., 2013).

However, in LMICs, specifically in SSA, people are still dying due to a lack of diagnoses, linkage to care, and late initiation of treatment (Hansoti et al., 2017). In this context, a key intervention in Zambia and South Africa has been carried out through the PopART trial. PopART is a randomised controlled trial providing early diagnosis and immediate linkage to care, both of which comprise a holistic set of interventions that may impact quality of life (Hayes et al., 2014). However, the direction of such effects is unclear. Several mechanisms in the process of care in this particular disease context may hinder or enable such effects. On the one hand, early diagnosis implies internally processing a potentially new, positive HIV status. The process of notifying family members and employers could cause an individual’s HRQoL to go down in the short term. Studies have shown this to be

particularly relevant when considering anxiety, depression, and self-care (Kagee & Martin, 2010; Olley et al., 2004; Reynolds et al., 2009). However, on the other hand, by improving access to treatment, the trial improves population health, as new infections are prevented, and, at the individual level, promotes better management of PLHIV, thus avoiding the deterioration of their health status. Improved health also leads to better well-being due to an enhanced ability to carry out daily activities (Beard et al., 2009; Peltzer & Phaswana-Mafuya, 2008), and decreased pain (Jelsma et al., 2005; Robberstad & Olsen, 2010), thus enabling better HRQoL.

Therefore, in this chapter, I assess the impact of PopART on HRQoL. It is likely, if present, that these effects vary across different subgroups of the population, including sex, socio-economic, education, or employment status, thereby leading to the possibility of inequality in treatment outcomes, compliance, or health outcomes.

There are several methods for understanding the underlying theoretical framework behind HRQoL. The conceptual framework of Wilson and Cleary (1995) is the most widely cited one, examining, as it does, determinants and causal pathways of HRQoL, and proposing a model to integrate clinical and psychosocial approaches to healthcare, specifically related to HRQoL (Ojelabi et al., 2017). Mohammed et al. (2021) provided great support for the Wilson and Cleary (1995) framework and helped me to shape my own. In short, I believe the most relevant background factors impacting how PLHIV experience HRQoL are shaped by: (a) socio-demographic background, including age, gender, ethnicity, and other traditional markers; (b) socio-economic factors, including income or wealth, primary education, secondary education, employment, formal or otherwise; (c) clinical determinants, including CD4 count, how long an individual has been on ART, including their adherence, and any further co-morbidities; and lastly (d) psychological factors, including stigma, marriage, and familial support.

This analysis covers some of these factors simply through the subgroups that have been chosen for analysis; gender, socio-economic status, and education provide us with a glimpse of the impact of the trial on both socio-demographic and socio-economic background. Furthermore, examining the subgroups of employed, formally employed, and unemployed provides further background on socio-economics. If an individual is infected with HIV, ART treatment is immediately initiated. However, if an HIV-infected individual is in the treatment group of the trial, linkage to care is overseen by the CHiPs workers. In

this way, a subset of clinical determinants is included in this analysis. Psychological factors, such as stigma, are noted to be of great relevance as a driving background factor but are not directly included in the analysis.

There are several mechanisms that may underlie the possible heterogeneity of trial outcomes on HRQoL. A few notable ones in the context of HIV are stigma (Earnshaw et al., 2018; Simbayi et al., 2007), HIV literacy – that is, the awareness of incentives for learning HIV status and treatment options (Wolf et al., 2007) – and risk behaviours (Fox, 2010; McGrath et al., 2015; Uchudi et al., 2012).

Stigma is prevalent following a positive diagnosis (Earnshaw et al., 2018; Simbayi et al., 2007), and it can impact both access to care (Earnshaw et al., 2018; Simbayi et al., 2007) and compliance with treatment (Dlamini et al., 2009; Mouala et al., 2006). While prevalent in the context of HIV, it is well documented that stigma impacts different subgroups of the population differently. Stigma has been found in some contexts to impact women much worse than men (Bhana et al., 2014), adding to the burden of the already greater HIV prevalence among women in SSA (Kako et al., 2011). Given the differential prevalence and impact of stigma on men and women, one would expect to see worse outcomes of the trial in terms of both HRQoL, especially in the mental health dimension of HRQoL (Kagee & Martin, 2010; Reynolds et al., 2009), and general trial effectiveness for women, as has been found in other interventions (Harper et al., 2014). For example, interventions to mitigate stigma have been found to successfully reduce stigma and enhance the quality of life in young men, but to increase stigma and decrease the quality of life in women (Bhana et al., 2014; Harper et al., 2014). Therefore, one would expect any effects of PopART on quality of life to be different between men and women.

The effectiveness of the trial in improving HRQoL may also differ across socio-economic status, through wealth and education. Lower levels of wealth and education are associated with low HIV literacy, which may impact the effectiveness of the trial through compliance with treatment (Hallman, 2005; Jung et al., 2013; Wawrzyniak et al., 2013). As treatment for HIV has evolved, HIV-infected individuals are now expected to reach ages where they will face chronic health problems, and thus general health literacy increases in importance (Wawrzyniak et al., 2013). Increasing treatment compliance, as is encouraged through a trial such as PopART, will thus help overall health literacy as the population ages. Those with a lower socio-economic status are considered to be the more at-risk population in

terms of health literacy, and are thus possibly less treatment compliant. In this case, a trial such as PopART may be less effective for these subgroups, thereby having a follow-on effect of creating less of an impact on HRQoL. This is consistent with research that has found that self-management interventions may have less of an impact on poorer individuals (Piette et al., 2000; Schaffler et al., 2018). Alternatively, individuals who are more educated are in a stronger position to learn about HIV, take advantage of the trial, increase treatment compliance, and thereby raise their HRQoL.

Employment may also be a factor that may affect the effectiveness of the trial. Working individuals typically enjoy a higher quality of life (Degroote et al., 2014; Hoffman, 1997). In the case of HIV, it is unclear a priori how any intervention such as the PopART trial may impact quality of life. For example, employers may require disclosure of an HIV-positive diagnosis, and working individuals may fear mistreatment or stigma in the workplace. Kohi et al. (2006) describe ways in which people living with HIV have their rights violated, including termination or refusal of employment and being denied an opportunity to work to earn an income. In contrast, Stephenson (2009) finds that higher levels of employment create opportunities for individuals to accrue not only economic resources but new ways of thinking and networking, which may not only empower PLHIV, but also enable them to access emotional support from co-workers. If the PopART trial improves awareness and diagnoses, it is unclear how heterogeneity among those who are employed or unemployed, and formally or informally employed, may ultimately impact on HRQoL.

Also unique to SSA is the spread of HIV due to migration, largely driven by moves to places of employment. Migrant workers in formal employment have been found to exhibit riskier sexual behaviour, and they have a higher HIV prevalence (McGrath et al., 2015). Even in industries such as sex work, it has been suggested that those who are employed informally have driven the spread of HIV, as informal sexual transactions are more difficult to track than formal sex work (Fox, 2010; Uchudi et al., 2012). As such, this is another example of why the PopART trial may exhibit heterogeneity around the formality of employment. The difference between formal and informal employment suggests that employment type has an impact on how the trial impacts HRQoL. Formal employers may have less stigma, and they may invest more in the well-being of their workers, thereby reinforcing the effect of the trial, and possibly encouraging compliance. In contrast, the informal sector may be less prone to offer these support systems and may offer more precarious conditions that make compliance

with trial treatment more difficult (Odek, 2013).

The expected direction of association between sex, wealth, education, employment, and HRQoL has just been summarised, as has been found in the literature. Unfortunately, these are only associations and not trial impacts. Thus, I am unable to take on a more formal hypothesis-driven approach to this analysis, presenting my work in comparison to that of the existing literature, due to the lack of existing evidence. Thus, I present here an exploratory analysis. The objective of this paper is to assess both the impact of PopART on HRQoL and the extent to which it varies across population subgroups. To the best of my knowledge, only one contribution has assessed this relationship thus far, and it found no major effects (Davis et al., 2022). The authors studied the difference in means in HRQoL dimensions of PLHIV in various waves, between the treatment and control arms, and found in general that there were no differences in HRQoL unless stratified by country, with the exception of the finding that treatment communities experienced lower pain and discomfort in the final trial wave. Davis et al. (2022) also stratified by sex and did not find significant results. I add to this paper in that I stratify on many different levels, using the full trial sample. I begin by estimating the impact of the total trial population on HRQoL, and I also consider its impact on different subgroups, defined by sex, wealth, education, and employment status. It is possible that the null effects at population level may be masking the heterogeneity of effects across population subgroups. My own work unlocks this plausible heterogeneity of the effect. Additionally, I add to the contribution by Davis et al. (2022) in that I make use of all of the waves of the trial data in a different manner, making use of panel data methodologies to assess the dynamics of the effects of the trial over time. The two papers are indeed complementary, with their focus on HRQoL findings in the PopART trial. Davis et al. (2022) investigate how the plausible negative short-term impacts of UTT randomised controlled trials lead to uncertainly over effects on HRQoL, and how this may bias morbidity effects found in the trial. One key difference between the papers is that Davis et al. (2022) focus only on PLHIV, whereas my paper incorporates the total sample of individuals included in the trial, both those infected with HIV and those who are HIV-negative. Davis et al. (2022) utilised two-stage beta regressions, comparing baseline versus individual alternative waves. My methodology, the difference-in-differences methodology, uses a before and after treatment approach in calculating the counterfactual.

The four main subgroups examined in this paper are particularly relevant determinants

of health in Zambia and South Africa. For example, South Africa has a very high unemployment rate. Latest results indicate that South Africa has an unemployment rate of 34% (Statistics South Africa, 2021). Of the 66% employed, 68% remain in formal employment, and 18% in informal, with the small amount remaining in agricultural and private households (Statistics South Africa, 2021). It is widely acknowledged that the unemployed have poorer health and poorer access to care (Goudge et al., 2009). However, what is not as well known is the protective barrier that formal employment, as compared to informal employment, provides against poor health and well-being, and access to care (le R Booyesen, 2003). Alferts and Rogan (2015) also find formal employment to be significantly associated with health in South Africa, and this is more marked for women than men. Employment and sex are not the only subgroups with demonstrated health inequalities. Phiri and Ataguba (2014) demonstrate inequalities in health utilisation in favour of the wealthier in Zambia, cite the lack of education, particularly among females, to be one of the key determinants of health in Zambia, and estimate that despite improved literacy rates, the numbers of females graduating from secondary schools to be only 18%.

Exploiting the randomised nature of the PopART trial and using a difference-in-differences methodology, my results show three significant findings, all indicating negative impacts on the relevant individuals. I find significant results in regard to HRQoL as a result of the PopART treatment lowering the ability to adopt self-care, which, by definition, is the ability to wash and dress, among individuals working formally. Also, I find a significant result diminishing the HRQoL dimension of Usual Activities, which, by definition, is working, studying, or doing housework, found in the primary-level educated subgroup. Additionally, a significant result is found in the HRQoL dimension of Pain or Discomfort, causing a negative impact for the primary-level educated subgroup. I will discuss these results further, including any different findings from Davis et al. (2022), in the Results section, 4.5.

The remainder of this chapter continues as follows: in Section 4.2 I discuss the background and related literature; in Section 4.3 I describe the data utilised; in Section 4.4 I outline the methodology followed; in Section 4.5 I discuss the results in greater detail; and in Section 4.6 I conclude with a discussion.

## 4.2 Background and Related Literature

It is broadly accepted that HIV impacts the quality of life. When available, combination antiretroviral therapy changes HIV from a terminal disease to a chronic condition (Cooper et al., 2017). However, despite near-normal life expectancy (Kharsany & Karim, 2016), the HRQoL of PLHIV is below that of the average population (Thomas et al., 2017). Evidence suggests that in addition to underlying clinical health issues, familial and social relationships, and social pressure, as well as stigma, are associated with decreased HRQoL (Cooper et al., 2017; Drewes et al., 2013). These effects are mediated by individual characteristics, with the impact of HIV on HRQoL differing across population subgroups such as sex, wealth, education, and employment. In Sub-Saharan Africa, the research on HRQoL based on sex is inconclusive. Some studies find that HIV disproportionately affects women (van der Kop et al., 2018), however there is very little research that studies the impact of HIV on HRQoL for men and women separately. Both van der Kop et al. (2018) and Vo et al. (2016) find, overall, a higher HRQoL in women with HIV. Van der Kop et al. (2018) conduct their study in Nairobi at the time a positive HIV test is received. Despite the overall positive higher scores in women, the authors note that for both sexes, higher quality of life scores are correlated with higher employment, higher education, and younger ages. The study by Vo et al. (2016) was conducted in six clinics in Ethiopia over a two-year period. In addition to the overall finding of higher female HRQoL results, the authors note that for both men and women, unemployment, psychological distress, food security, and low CD4+ counts are associated with lower HRQoL results. In contrast, another study conducted in Ethiopia by Tesfay et al. (2015) found that women have overall lower HRQoL scores. The authors studied PLHIV in public institutions in Mekelle Town, northern Ethiopia. They noted that for both males and females, a high level of stigma was a marker of a low psychological quality of life.

Results for high-income countries differ greatly from what is found in SSA. In high-income countries, P´erez et al. (2009) and Degroote et al. (2014) noted that, on average, women are found to report lower HRQoL. The authors attributed this to men’s more stoic attitudes, citing studies in the US and Puerto Rico (Mrus et al., 2005; Rao et al., 2007), and women’s feelings of guilt in a study in Sweden (Cederfjäll et al., 2001). Additionally, according to a study in the US, women are found to be more likely to have mood, anxiety,

or psychosomatic disorders (Mrus et al., 2005).

Degroote et al. (2014) state that a lower educational status could be associated with a lower ability to understand therapy recommendations, which in turn would lead to less knowledgeable, less involved patients with a lower HRQoL, who ultimately might be less compliant with drugs, hide diagnoses from friends and family, or be reluctant to return to work (Park-Wyllie et al., 2007). Da Silva et al. (2013) find an association between a low quality of life and “believing oneself to be ill”, just as there is an association with a lower quality of life from continuing to be uninformed about one’s own status. The authors note that this is consistent with theories on education; some assume that higher education may be related to better social skills, thus helping an individual as they search for emotional support. A timely diagnosis and access to treatment and support could mitigate these issues and prevent HRQoL from being impaired due to patients being unaware of their HIV status, or from fear (da Silva et al., 2013). However, an early diagnosis may not necessarily improve the quality of life, as individuals must face the reality of a diagnosis. Lindayani et al. (2018) identify this concept as self-stigma, the personal fear of burdening others with a new diagnosis, or of being accepted into the HIV community. As mentioned above, interventions to counteract stigma may be impacted differently by the sex, socio-economic, or employment status of those the intervention is trying to reach (Bhana et al., 2014; Harper et al., 2014; Lindayani et al., 2018).

Socio-economic status, particularly wealth and education, are considered to be key determinants of HRQoL in PLHIV. Mafirakureva et al. (2016) conducted a cross-sectional survey in a hospital in Zimbabwe evaluating HRQoL in patients and found that a higher level of HRQoL was positively and significantly related to income, education, and employment. In their study in Ethiopia, Tesfay et al. (2015) also found that income was a significant factor in HRQoL scores for both men and women. Additional studies in South Africa and Uganda, respectively (Jelsma & Ferguson, 2004; Stangl et al., 2007), obtained similar findings, noting that education and employment are closely related to income, and showed significant relationships.

Employment status is another factor found in the literature to explain differences in HRQoL in PLHIV. Degroote et al. (2014) suggest that employment is a positive predictor of both physical and mental health status. As employment comprises a significant portion of an individual’s day, this suggests that it provides structure, a social network, and a role

identity, going far beyond the role of simply providing earnings, thus leading to a higher HRQoL (Degroote et al., 2014; Hoffman, 1997). However, it is likely that there is a reverse causation in the case of HRQoL, as a high HRQoL might be necessary to work (Degroote et al., 2014; Rueda et al., 2011). In another study by Odek (2013), the author studies the link between formal employment and HRQoL in South Africa. The author notes specifically that an awareness of workplace HIV policies and HIV status disclosure to colleagues are the hallmarks of formal employment policies, and finds that formally employed participants report higher HRQoL scores than those who are informally employed.

From the literature above, we see that HRQoL varies across individuals with different characteristics. Thus, heterogeneity in HRQoL across different subgroups of the population may be mitigated by different types of interventions, including social support interventions, stigma reductions, treatment, and test and treat interventions, providing diagnoses and access to care. One example of this latter category is a study by Gakhar et al. (2013), a review covering 26 different studies examining the relationship between different drug regimens and HRQoL outcomes. Unanimously, in all studies, HRQoL was maintained or improved by antiretroviral therapy.

The PopART trial, as explored in this paper, falls into this latter category, providing a comprehensive approach to universal testing and treatment. PopART offers early diagnosis via home testing, and immediate linkage to care. As posited by the literature, it is unlikely that individuals responded uniformly to PopART. My research expands upon the work of Davis et al. (2022), who study the difference in HRQoL means among arms of the trial, finding no differences in HRQoL except in the dimension of pain/discomfort.

Similarly to Davis et al. (2022), I assess the average impact of the trial on HRQoL, as well as the different dimensions of the HRQoL index, namely the dimensions of self-care, usual activities such as work or study, pain/discomfort, anxiety or depression, and mobility. I build on the paper by Davis et al. (2022) with two significant contributions. First, I improve upon the analysis already completed by deploying difference-in-differences methodologies to better identify the impact of the trial. Since the trial was deployed as a randomised experiment, it has been designed to be well balanced in observing characteristics between treated and control groups. Deploying difference-in-differences methodologies and controlling for potential imbalances in confounders enables a reduction in the variability in the observed outcome, and thus provides more precise estimates of the treatment effect. The

second main contribution of this study is that I assess the heterogeneity of trial effects across sex, wealth, education, employment, and type of employment. By studying these subgroups, I hope to gain insight into who benefited the most, and least, from the trial in terms of health-related quality of life, and how that information might be utilised going forward for future trials.

### 4.3 Data

This paper utilises data from all four waves of the PopART trial, a three-arm cluster randomised controlled trial performed between 2013 and 2018 in 21 communities in Zambia and South Africa. In each of the communities, a baseline population cohort was surveyed, consisting of a random sample of 2,500 individuals in each of the 21 communities, amounting to approximately 48,000 individuals in total, post attrition. These individuals were surveyed at baseline, having enrolled between December 2013 and March 2015, before the intervention occurred, and again at 12, 24, and 36 months following the original survey in Waves 2–4 (Hayes et al., 2019). The communities were divided into seven triplets consisting of three treatment arms. Four triplets were in Zambia and three in South Africa, with the triplets serving the purpose of reducing between-community variance in baseline HIV incidence and prevalence. The triplets were matched geographically to proxy for partnering HIV services. Treatment was assigned and implemented in two of the three arms into which the 21 communities were split (Hayes et al., 2014).

Arm A was assigned the full intervention, including home-based testing and immediate linkage to care. Arm B was assigned the intervention, however following national treatment guidelines (Hayes et al., 2014). From 2016, international guidelines changed (WHO, 2015), and effectively Arms A and B were the same, which is how they are treated in this chapter. Arm C received standard national care (Hayes et al., 2014). Thus, for analysis purposes, I utilise one treatment population (Arms A and B) and one control population (Arm C). For a full outline of the different interventions, see Figure 12 in Chapter 3. The HRQoL questionnaire was conducted in all four waves of the trial and given to each individual surveyed.

For consistency purposes, following the methodology of Chapter 3, Triplet 2 has been excluded from all analyses in this chapter due to variance between treatment and control arms because of the cholera outbreak and other socio-economic factors (Hayes et al., 2014; UNICEF, 2016). All analyses in this chapter are assessed using six triplets. Please review Section 3.3 for further details.

#### 4.3.1 Key Dependent Variables

To assess an individual's HRQoL, participants in the PopART trial are asked to respond to the EuroQol five-dimension, five-level questionnaire (EQ-5D-5L) (EuroQol, 2021). The EQ-5D-5L measures quality of life over five dimensions on a scale of 1 (meaning the individual has no problems) to 5 (meaning they are unable to perform the task). These five variables are five of the six key dependent variables in this analysis. The first dimension, "*Qolself*", is a self-care response, assessing if the individual feels they have no issues, slight, moderate, severe, or are unable to "wash and dress myself".

The second dimension is "*Qolact*". Again, as with all the variables on the 1–5 scale, the answers indicate "no, slight, moderate, severe, or inability" in "doing my usual activities, e.g. work, study, housework, family, or leisure activities".

The third, fourth, and fifth dimensions are "*Qolpain*", "*Qolanx*", and "*Qolmob*". The same five-point scale holds as described above for each of the variables. "*Qolpain*" indicates "pain or discomfort". For "*Qolanx*", the five-point scale applies to whether the individual is "anxious or depressed", and for "*Qolmob*", the definition given by the PopART questionnaire is the ability to be "walking about", a measure of mobility. I use these dimensions as outcomes of interest.

Finally, my last and sixth dependent variable, "*EQ5D*", is built from a combination of the above five variables and weighted by a valuation of health states, which are measured on an interval scale. A valuation of 1 generally represents perfect health and aligns with the EQ-5D-5L response of 1 where an individual claims they have no problems. At the extreme end, 0 maps as being equivalent to death. Due to valuation differences that change by country and culture (Pickard et al., 2019), I utilise the closest valuation available to suit Sub-Saharan Africa, which is a Zimbabwean valuation. Given that the data is skewed towards 1 for most of the indices, as can be seen in Tables 26–31, following the literature (Janssen et al., 2013; Van Hout et al., 2012), the scores are adjusted downwards, capping the top value score at 0.9 rather than 1. The lowest score, as can be seen in the summary statistics in Table 19, falls slightly under 0. Thus, the composite score of EQ5D's range of (-0.1–0.9) at baseline coincides with the five dimensions' range of 1.0–5.0) at baseline.

#### 4.3.2 Covariates

The covariates in this exploratory analysis have been chosen based on evidence from the literature on key socio-determinants of HRQoL. I have chosen to include sex (Tsfay et al., 2015; van der Kop et al., 2018; Vo et al., 2016), wealth and educational level achieved (Mafirakureva et al., 2016; Tsfay et al., 2015), and employment status (Odek, 2013; van der Kop et al., 2018; Vo et al., 2016) as the key socio-demographic variables. These variables are noted as “*Sex*”, “*Wealth*”, “*Education*”, and “*Working*” in all models in Tables 22–33.

“*Sex*” is a binary indicator based on the PopART question of “household member sex”, taking on the value of 0 if the respondent is a female and 1 if it is a male. Tsfay et al. (2015), van der Kop et al. (2018), and Vo et al. (2016) demonstrate that the role of sex significantly impacts the direction of impact that HIV has on an individual’s HRQoL.

Wealth and educational achievement are common indicators of socio-economic status in PLHIV and are key determinants of HRQoL. Both wealth and education have been generally found to have positive associations with HRQoL (Mafirakureva et al., 2016; Odek, 2013; Tsfay et al., 2015; van der Kop et al., 2018; Vo et al., 2016). “*Wealth*” is a continuous variable built from a PCA of Zambia and South Africa separately, and then combined, taking the means of country-level counts of buildings, floor and sanitation panels, as well as individual-level ownership surveys of cellphones, bicycles, cars, televisions, and computers, for example. It is possible for the PCA to take on a negative value based on resulting eigenvalues, showing that there is an inverse relationship between a factor and a variable. The “*Education*” indicator is constructed to take on four possible values: no education, between grades 1 and 7, between grades 8 and 12, and college/university or other. In the analysis shown in Tables 22–32, in models “6-PrimaryEd” and “7-SecondEd”, “PrimaryEd” includes no education, and responses between grades 1 and 7 to “*Education*” level. “SecondEd” includes between grades 8 and 12, as well as college/university or other. I chose to stratify due to the skewed distribution of the data, thus I might assume a uniform distribution within strata, and that all strata have the same relative variation, as per Horgan (2006).

Employment has also been found to be a significant, positive indicator of HRQoL, as employment offers structure, social contacts, and personal identity, in addition to a stable income (Hoffman, 1997; van der Kop et al., 2018; Vo et al., 2016). The indicator “*Working*”

was built to capture employment status. It is a binary indicator signalling whether the individual is working at the time of the survey or not. This variable does not capture whether an individual is seeking to find employment and so should not be considered as a measure to assess unemployment. The second set of models in the analysis section, Tables 23, 25, 27, 29, 31, and 33, are stratified by employment. Hence, I have created variables to capture the level and type of an individual's employment. Odek (2013) and Booysen et al. (2007) find formal employment positively and significantly contributes to the quality of life. Also, I include here variables if one is "*Working*", a binary variable for if an individual is employed or unemployed. "*Workformal*" is a binary variable representing those who work formally, or not; "*Workformal*" takes on the value of 1 if working formally and the value of 0 if working informally. These categories are constructed from the PopART questionnaire: "In your main job, what type of job do you do?" Formal workers include formal wage employment, both full- and part-time. Informal employment includes occasional, seasonal, and casual employment, any form of self-employment, and other.

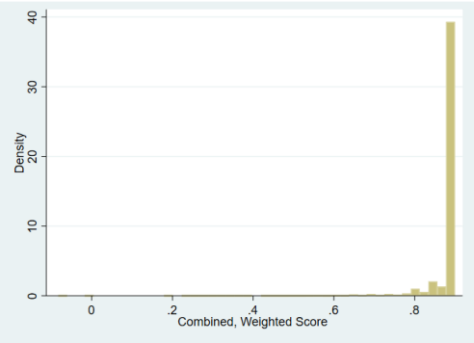
#### **4.3.3 Descriptive Statistics**

Tables 19–21 display descriptive statistics for the total sample in the analysis, including the treated population and control population. I have noted the pre-trial, Wave 1 data as "baseline", and the post-trial initiation results, an average of Waves 2–4, as "average treated waves". In Table 19, focusing on the key dependent variables, "*EQ5D*", "*Qolself*", "*Qolact*", "*Qolpain*", "*Qolanx*", and "*Qolmob*", looking at the mean values we see from baseline to initiated treatment a slight increase in "*EQ5D*", my overall measure of well-being. As can be seen from the descriptive statistics in Tables 19–21, the five domains of the HRQoL data are presented, as well as the key covariates used in the analysis. A total of 31,170 respondents completed the HRQoL questionnaire in the baseline interview. Of these, 20,802 received the treatment in the trial, and 10,368 resided in a control community. Due to the combination of Arms A and B, as discussed above, there is approximately twice the observation count in the treated group, as compared to the control group. Looking at the statistics in the average treated waves in Table 19, we have a slightly lower observation count for "*EQ5D*", at 30,839, as well as the other five HRQoL dimensions, indicating some net attrition over the course of the trial.

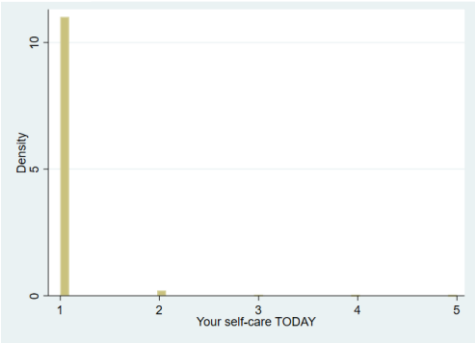
Looking at the baseline population cohort, as shown in Table 19, we see that out of the total sample size, only 25.5% of the respondents were men. The mean wealth was relatively low. As discussed in Section 4.3.2, wealth is a continuous index variable built from a PCA analysis, which is able to take on negative values, as is evident from the minimum index value of -5.9 in Table 19. The mean of the wealth index is 0.1, and the max is 3.8. Among those surveyed, 30.2% were employed. The sample was quite evenly split between those who worked formally and those who worked informally, with 49.6% of the employed sample working in a formal occupation and 50.4% working informally. The sample was relatively highly educated, with a mean education level of 1.92, whereas 2.0 would indicate completion of secondary education. Although not shown in Table 19, the PopART data provide further detail on education. At baseline, 1.2% of the sample has no education, 17.3% of the sample is educated at between grades 1 and 7 (primary-level schooling), 75.4% is educated at between grades 8 and 12 (secondary-level education), and 6.2% had received a college or university-level education.

Examining the “average treated waves” results, which is an average of the data from Waves 2 to 4, comparing between the treatment and control groups once treatment was initiated we see a slightly higher average “*EQ5D*” score in both the treatment and control groups. Table 20 shows that “*EQ5D*” for the treated has slightly risen to 0.889 in the average treated waves, compared to 0.888 in the baseline data. Looking at the composite five indicators that comprise “*EQ5D*”, it is “*Qolmob*” that has taken the greatest fall, thereby lowering the composite variable, “*EQ5D*”. This is surprising as one would not expect mobility to be immediately impacted following a potentially positive HIV diagnosis, although there have been studies showing that mobility is one of the most common reasons for disengagement from care (Bisnauth et al., 2021). However, if one looks at the control group results in Table 21, similar findings are shown, so this may be driven by an underlying systematic blockage at the time of access to ART. Similarly, wealth rose in the treatment group but did not rise in the control group. In the treatment and control groups, there is a very slight change in employment, with employment falling by 1% in each group post treatment initiation.

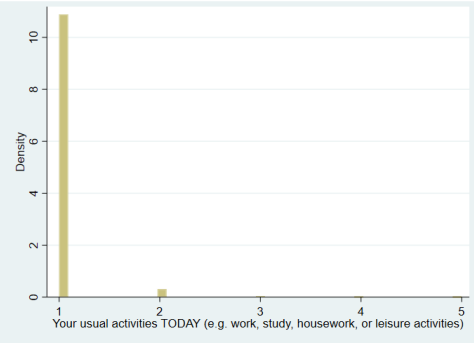
**Figure 26**  
*Combined Score Distribution*



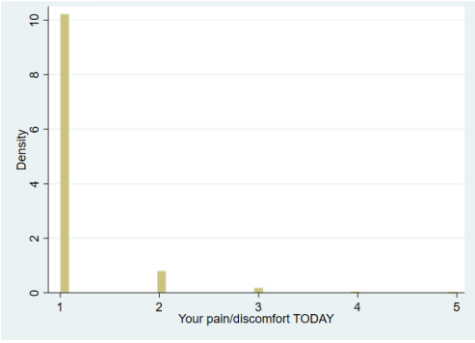
**Figure 27**  
*Self-Care Distribution*



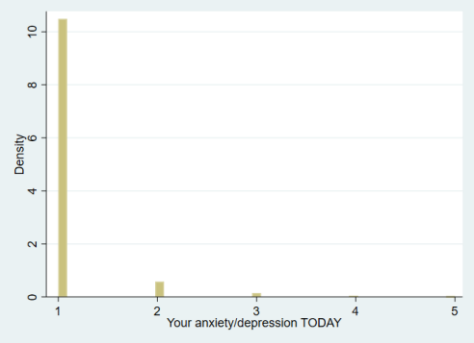
**Figure 28**  
*Usual Activities Distribution*



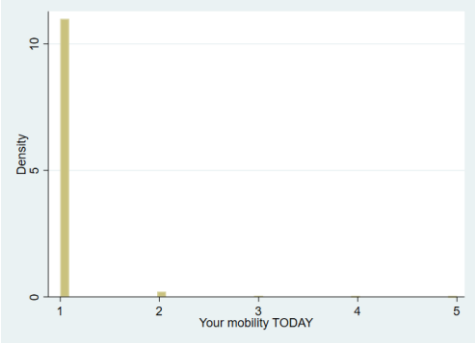
**Figure 29**  
*Pain Distribution*



**Figure 30**  
*Anxiety Distribution*



**Figure 31**  
*Mobility Distribution*



**Table 18**  
*HRQoL Dimensions – Five Key Variables*

| Dimension Variable                      | Problem                        | Health Scoring of Problems |                 |                   |                 |                        |
|-----------------------------------------|--------------------------------|----------------------------|-----------------|-------------------|-----------------|------------------------|
|                                         |                                | 1                          | 2               | 3                 | 4               | 5                      |
| Self-Care Today ( <i>Qo/self</i> )      | Washing and dressing myself    | No problems                | Slight problems | Moderate problems | Severe problems | Unable to perform task |
| Usual Activities ( <i>Qo/lact</i> )     | Doing work, study, & housework | No problems                | Slight problems | Moderate problems | Severe problems | Unable to perform task |
| Pain or Discomfort ( <i>Qo/pain</i> )   | Pain or discomfort             | No problems                | Slight problems | Moderate problems | Severe problems | Unable to perform task |
| Anxiety or Depression ( <i>Qo/anx</i> ) | Anxious or depressed           | No problems                | Slight problems | Moderate problems | Severe problems | Unable to perform task |
| Mobility ( <i>Qo/mob</i> )              | Walking about                  | No problems                | Slight problems | Moderate problems | Severe problems | Unable to perform task |

**Table 19**  
*HRQoL Summary Statistics – Total Sample*

| <b>Baseline</b>                                             | Mean  | SD    | Min  | Max | N      |
|-------------------------------------------------------------|-------|-------|------|-----|--------|
| Combined, Weighted Score ( <i>EQ5D</i> )                    | 0.887 | 0.042 | -0.1 | 0.9 | 31,170 |
| Self-Care Today ( <i>Qolself</i> )                          | 1.031 | 0.222 | 1.0  | 5.0 | 31,192 |
| Usual Activities – Work, Study, Housework ( <i>Qolact</i> ) | 1.027 | 0.199 | 1.0  | 5.0 | 31,292 |
| Pain or Discomfort ( <i>Qolpain</i> )                       | 1.040 | 0.243 | 1.0  | 5.0 | 31,294 |
| Anxiety or Depression ( <i>Qolanx</i> )                     | 1.113 | 0.390 | 1.0  | 5.0 | 31,294 |
| Mobility ( <i>Qolmob</i> )                                  | 1.097 | 0.381 | 1.0  | 5.0 | 31,282 |
| Employment Status ( <i>Working</i> )                        | 0.302 | 0.459 | 0.0  | 1.0 | 31,325 |
| Male/Female ( <i>Sex</i> )                                  | 0.255 | 0.436 | 0.0  | 1.0 | 31,316 |
| Wealth ( <i>Wealth</i> )                                    | 0.100 | 1.681 | -5.9 | 3.8 | 31,325 |
| Education Status ( <i>Education</i> )                       | 1.920 | 0.476 | 0.0  | 3.0 | 31,325 |
| Working Formally ( <i>Workformal</i> )                      | 0.496 | 0.500 | 0.0  | 1.0 | 7,916  |
| <b>Average Treated Waves</b>                                | Mean  | SD    | Min  | Max | N      |
| Combined, Weighted Score ( <i>EQ5D</i> )                    | 0.890 | 0.029 | 0.3  | 0.9 | 30,839 |
| Self-Care Today ( <i>Qolself</i> )                          | 1.027 | 0.165 | 1.0  | 5.0 | 30,858 |
| Usual Activities – Work, Study, Housework ( <i>Qolact</i> ) | 1.019 | 0.137 | 1.0  | 5.0 | 30,855 |
| Pain or Discomfort ( <i>Qolpain</i> )                       | 1.032 | 0.166 | 1.0  | 5.0 | 30,848 |
| Anxiety or Depression ( <i>Qolanx</i> )                     | 1.096 | 0.282 | 1.0  | 5.0 | 30,852 |
| Mobility ( <i>Qolmob</i> )                                  | 1.060 | 0.255 | 1.0  | 5.0 | 30,853 |
| Employment Status ( <i>Working</i> )                        | 0.289 | 0.453 | 0.0  | 1.0 | 30,917 |
| Male/Female ( <i>Sex</i> )                                  | 0.413 | 0.418 | 0.0  | 1.0 | 30,873 |
| Wealth ( <i>Wealth</i> )                                    | 0.164 | 1.453 | -5.9 | 3.7 | 30,917 |
| Education Status ( <i>Education</i> )                       | 1.918 | 0.488 | 0.0  | 3.0 | 30,917 |
| Working Formally ( <i>Workformal</i> )                      | 0.493 | 0.457 | 0.0  | 1.0 | 17,390 |

“Baseline” data were taken before the initiation of trial treatment. “Average treated waves” is an average of the data from Waves 2 to 4. The composite dependent variable *EQ5D* is capped at 0.9 in keeping with Zimbabwean utility weighting methods (Janssen et al., 2013; Van Hout et al., 2012), in contrast to the five dependent variables *Qolself*, *Qolact*, *Qolpain*, *Qolanx*, and *Qolmob*, where 1.0 is the highest score possible, representing “no” problems. One individual in the data set responded with such low answers across all dimensions that with the Zimbabwean weightings, their *EQ5D* score was less than 0. *Wealth* was built from a PCA. If *Wealth* takes on a negative value, as is shown in the minimum value above, this is based on the eigenvalues in the PCA, showing that there is an inverse relationship between a factor and a variable.

**Table 20**  
*HRQoL Summary Statistics – Treated*

| <b>Baseline</b>                                             | Mean   | SD    | Min  | Max | N      |
|-------------------------------------------------------------|--------|-------|------|-----|--------|
| Combined, Weighted Score ( <i>EQ5D</i> )                    | 0.888  | 0.039 | -0.1 | 0.9 | 20,802 |
| Self-Care Today ( <i>Qolself</i> )                          | 1.026  | 0.204 | 1.0  | 5.0 | 20,823 |
| Usual Activities – Work, Study, Housework ( <i>Qolact</i> ) | 1.023  | 0.180 | 1.0  | 5.0 | 20,898 |
| Pain or Discomfort ( <i>Qolpain</i> )                       | 1.035  | 0.226 | 1.0  | 5.0 | 20,899 |
| Anxiety or Depression ( <i>Qolanx</i> )                     | 1.100  | 0.367 | 1.0  | 5.0 | 20,899 |
| Mobility ( <i>Qolmob</i> )                                  | 1.097  | 0.379 | 1.0  | 5.0 | 20,888 |
| Employment Status ( <i>Working</i> )                        | 0.299  | 0.458 | 0.0  | 1.0 | 20,922 |
| Male/Female ( <i>Sex</i> )                                  | 0.263  | 0.440 | 0.0  | 1.0 | 20,917 |
| Wealth ( <i>Wealth</i> )                                    | -0.008 | 1.764 | -5.9 | 3.7 | 20,922 |
| Education Status ( <i>Education</i> )                       | 1.930  | 0.472 | 0.0  | 3.0 | 20,922 |
| Working Formally ( <i>Workformal</i> )                      | 0.484  | 0.500 | 0.0  | 1.0 | 5,455  |
| <b>Average Treated Waves</b>                                | Mean   | SD    | Min  | Max | N      |
| Combined, Weighted Score ( <i>EQ5D</i> )                    | 0.889  | 0.030 | 0.3  | 0.9 | 20,367 |
| Self-Care Today ( <i>Qolself</i> )                          | 1.029  | 0.174 | 1.0  | 5.0 | 20,384 |
| Usual Activities – Work, Study, Housework ( <i>Qolact</i> ) | 1.021  | 0.144 | 1.0  | 5.0 | 20,381 |
| Pain or Discomfort ( <i>Qolpain</i> )                       | 1.034  | 0.171 | 1.0  | 5.0 | 20,376 |
| Anxiety or Depression ( <i>Qolanx</i> )                     | 1.095  | 0.277 | 1.0  | 5.0 | 20,379 |
| Mobility ( <i>Qolmob</i> )                                  | 1.069  | 0.273 | 1.0  | 5.0 | 20,379 |
| Employment Status ( <i>Working</i> )                        | 0.284  | 0.451 | 0.0  | 1.0 | 20,427 |
| Male/Female ( <i>Sex</i> )                                  | 0.424  | 0.418 | 0.0  | 1.0 | 20,389 |
| Wealth ( <i>Wealth</i> )                                    | 0.127  | 1.503 | -5.9 | 3.7 | 20,427 |
| Education Status ( <i>Education</i> )                       | 1.930  | 0.486 | 0.0  | 3.0 | 20,427 |
| Working Formally ( <i>Workformal</i> )                      | 0.490  | 0.455 | 0.0  | 1.0 | 11,803 |

“Baseline” data were taken before the initiation of trial treatment. “Average treated waves” is an average of the data from Waves 2 to 4. The composite dependent variable *EQ5D* is capped at 0.9 in keeping with Zimbabwean utility weighting methods (Janssen et al., 2013; Van Hout et al., 2012), in contrast to the five dependent variables *Qolself*, *Qolact*, *Qolpain*, *Qolanx*, and *Qolmob*, where 1.0 is the highest score possible, representing “no” problems. One individual in the data set responded with such low answers across all dimensions that with the Zimbabwean weightings, their *EQ5D* score was less than 0. *Wealth* was built from a PCA. If *Wealth* takes on a negative value, as is shown in the minimum value above, this is based on the eigenvalues in the PCA, showing that there is an inverse relationship between a factor and a variable.

**Table 21**  
*HRQoL Summary Statistics – Control*

| <b>Baseline</b>                                             | Mean  | SD    | Min  | Max | N      |
|-------------------------------------------------------------|-------|-------|------|-----|--------|
| Combined, Weighted Score ( <i>EQ5D</i> )                    | 0.885 | 0.048 | -0.0 | 0.9 | 10,368 |
| Self-Care Today ( <i>Qolself</i> )                          | 1.040 | 0.255 | 1.0  | 5.0 | 10,369 |
| Usual Activities – Work, Study, Housework ( <i>Qolact</i> ) | 1.035 | 0.234 | 1.0  | 5.0 | 10,394 |
| Pain or Discomfort ( <i>Qolpain</i> )                       | 1.051 | 0.275 | 1.0  | 5.0 | 10,395 |
| Anxiety or Depression ( <i>Qolanx</i> )                     | 1.139 | 0.432 | 1.0  | 5.0 | 10,395 |
| Mobility ( <i>Qolmob</i> )                                  | 1.095 | 0.385 | 1.0  | 5.0 | 10,394 |
| Employment Status ( <i>Working</i> )                        | 0.309 | 0.462 | 0.0  | 1.0 | 10,403 |
| Male/Female ( <i>Sex</i> )                                  | 0.237 | 0.425 | 0.0  | 1.0 | 10,399 |
| Wealth ( <i>Wealth</i> )                                    | 0.317 | 1.477 | -5.9 | 3.8 | 10,403 |
| Education Status ( <i>Education</i> )                       | 1.901 | 0.484 | 0.0  | 3.0 | 10,403 |
| Working Formally ( <i>Workformal</i> )                      | 0.523 | 0.500 | 0.0  | 1.0 | 2,461  |
| <b>Average Treated Waves</b>                                | Mean  | SD    | Min  | Max | N      |
| Combined, Weighted Score ( <i>EQ5D</i> )                    | 0.891 | 0.027 | 0.3  | 0.9 | 10,472 |
| Self-Care Today ( <i>Qolself</i> )                          | 1.021 | 0.146 | 1.0  | 5.0 | 10,474 |
| Usual Activities – Work, Study, Housework ( <i>Qolact</i> ) | 1.016 | 0.121 | 1.0  | 5.0 | 10,474 |
| Pain or Discomfort ( <i>Qolpain</i> )                       | 1.027 | 0.155 | 1.0  | 5.0 | 10,472 |
| Anxiety or Depression ( <i>Qolanx</i> )                     | 1.098 | 0.292 | 1.0  | 5.0 | 10,473 |
| Mobility ( <i>Qolmob</i> )                                  | 1.044 | 0.215 | 1.0  | 5.0 | 10,474 |
| Employment Status ( <i>Working</i> )                        | 0.299 | 0.458 | 0.0  | 1.0 | 10,490 |
| Male/Female ( <i>Sex</i> )                                  | 0.392 | 0.418 | 0.0  | 1.0 | 10,484 |
| Wealth ( <i>Wealth</i> )                                    | 0.236 | 1.348 | -5.1 | 3.7 | 10,490 |
| Education Status ( <i>Education</i> )                       | 1.894 | 0.490 | 0.0  | 3.0 | 10,490 |
| Working Formally ( <i>Workformal</i> )                      | 0.501 | 0.461 | 0.0  | 1.0 | 5,587  |

“Baseline” data were taken before the initiation of trial treatment. “Average treated waves” is an average of the data from Waves 2 to 4. The composite dependent variable *EQ5D* is capped at 0.9 in keeping with Zimbabwean utility weighting methods (Janssen et al., 2013; Van Hout et al., 2012), in contrast to the five dependent variables *Qolself*, *Qolact*, *Qolpain*, *Qolanx*, and *Qolmob*, where 1.0 is the highest score possible, representing “no” problems. One individual in the data set responded with such low answers across all dimensions that with the Zimbabwean weightings, their *EQ5D* score was less than 0. *Wealth* was built from a PCA. If *Wealth* takes on a negative value, as is shown in the minimum value above, this is based on the eigenvalues in the PCA, showing that there is an inverse relationship between a factor and a variable.

## 4.4 Methodology

### 4.4.1 Difference-in-Differences

This paper will utilise a difference-in-differences (DID) method for estimating the causal impact of the PopART trial on HRQoL, utilising the four waves of PopART data. DID estimates the effects of the PopART intervention by comparing the change in HRQoL in treated communities, pre- and post-intervention, with the changes in HRQoL in the untreated communities, pre- and post-intervention. The DID methodology assumes that in the absence of a treatment programme there would be no difference in HRQoL over time between those in the treated and untreated communities, which is validated given that PopART is a cluster randomised trial. Treatment is at community level.

The base case DID specification may be written as follows, following the work of Angrist and Pischke (2008), Card and Krueger (1994), and Miraldo et al. (2018), and utilising the notation of Hayes and Moulton (2017):

$$y_{kjt} = \beta_0 + \beta_1 X_k + \beta_2 X_{kt} + \beta_3 (Treated_{jt}) + \beta_4 (Post_t) + \beta_5 (Policy_{jt}) + \beta_6 (wave_t) + \beta_7 (triplet_j) + \eta_{kjt} \quad (11)$$

Each outcome variable  $y_{kjt}$  is one of the set of five dependent variables mentioned above in Section 4.3.1, representing a dimension of the HRQoL, or the compiled total variable *EQ5D* for each individual  $k$  living in community  $j$  during wave  $t$ .  $Treated_{jt}$  is a dummy variable if an individual lives in a treated community, and 0 otherwise.  $Treated_{jt}$  thus controls for systematic differences in the dependent variables across the treatment and control communities that are unrelated to the PopART policy.  $Post_t$  is equal to 1 for the waves where the treatment was initiated in the trial. In this case, treatment was initiated by the trial in Waves 2–4.  $Post_t$  is a binary variable, so it takes on the value of 0 in Wave 1 in this instance. The coefficient of interest is  $\beta_5$ , the DID coefficient on the policy variable,  $Policy_{jt}$ , which is formed from the two variables  $Treated_{jt} * Post_t$ .  $Policy_{jt}$  takes on the value of 1 for those individuals in the treated communities, and a value of 0 in the control communities, once treatment has been initiated.

In addition, I have controlled for both time-invariant and time-variant individual covariates,

which help explain differences in outcomes across individuals, as indicated by  $X_k$  and  $X_{kt}$ , respectively. Please refer to the above Data section, 4.3, where the covariates are described in Section 4.3.2.

Lastly, I include triplet dummies,  $triplet_j$ , to control for any systematic differences across triplets that may confound the analyses. Through trial design, random allocation of communities within triplets to treatment arms ensures that any differences among arms, apart from the intervention effects, are due to chance (Hayes & Moulton, 2017). Thus,  $triplet_j$ , by proxy, also controls for any time-invariant community-specific effects, to control for any differences in the outcome variable due to differences among communities and unrelated to the policy. Additionally, time fixed effects are included in  $wave_t$ , which control for any wave-specific effects over time. These represent a standard time fixed effect over the period of the trial. Thus, the random error  $\eta_{kjt}$  is based on the assumption that cluster-level results for each treatment arm come from the same distribution, in the absence of an intervention effect. Hence, random errors are clustered at the triplet level.

In order to explore the impact of the trial on different subgroups, I employ stratification to isolate the heterogeneous impacts of the trial on different populations. Thus, I have organised the findings of the trial by the six dependent variables: the composite variable *EQ5D*, followed by the five additional domains of the HRQoL. For each dependent variable, I present the base case scenario, which includes the total sample available. The following columns are constrained by stratifying by various subgroups. First, I stratify by sex, first presenting the results for females, then those for males. Next, I present the results stratified by wealth, split around the median (noted as low and high), and lastly I stratify by education. Primary education includes primary education and below (none). Those with no education make up less than 1% of the entire sample. Secondary education includes secondary education and above (college and higher education). Those with a college education represent approximately 7% of the population.

I then stratify conditional upon employment and type of employment. For comparative purposes I repeat the base case for each dependent variable. I then present the results stratified by being employed and unemployed, or working in the formal or informal sector. Due to the use of fixed effects, not all variables are estimated in the tables because of their time-invariant nature. All regressions include individual control variables, and triplet and wave fixed effects.

## 4.5 Results

The tables in this section present the outcomes of the DID specification for each of the six main dependent variables. First, in Tables 22 and 23, I present the results for the composite variable, *EQ5D*. In the first column of Table 22 I present the base case, which includes the entire sample. Next, I present the stratification results, as was introduced above in the Methodology section, 4.4. First, I present stratification by subgroups of sex, wealth, and education. The results in Table 22 demonstrate that the PopART policy had, on average, a negative, insignificant effect on the combined, weighted HRQoL score (*EQ5D*). Similar findings are found when the sample is stratified. In particular, the trial has no impact on overall HRQoL for men or women, and those primary or secondary educated (Table 22), the employed (formal and informal employment), and unemployed (Table 23).

With regard to the different dimensions of HRQoL, Table 24 displays results for self-care (*Qo/self*) and shows that the trial did not have an impact on the ability to perform self-care activities. The same finding holds when the sample is stratified by sex, wealth, education, and employment.

However, conditioning on employment results show that the trial had a negative impact on the ability to conduct self-care activities of those working in the formal sector (Table 25). A significant effect of 0.018 points is found for those individuals that work in the formal sector (Table 25; Model 6-Formal; p-value <0.100). Remember that in the survey, a higher score represents a worsened health state, thus a positive coefficient implies a worsened outcome for the treated subgroup compared to the control subgroup. Possibly, those that are formally employed had more worry attached to learning a diagnosis, or felt less flexibility in their ability to take time off to seek treatment. There has been evidence of decreases in HRQoL in months following diagnosis for those that are employed, although these have been shown to recover to positive increases in HRQoL as years pass following diagnosis (Honiden et al., 2006). As for those employed in the informal sector, the trial did not impact their ability to conduct self-care activities (Table 25; Model 7-Informal; p > 0.100). Tables 26 and 27 outline the results of any trial impact on usual activities (*Qo/act*). We see a consistent absence of trial effect across all subgroups, including in the specifications

stratified by sex, wealth, education, employment, and employment type. There is one significant finding in this HRQoL dimension, and that is for the primary education subgroup, with those exposed to the trial exhibiting a *Qolact* score higher by 0.056 than for controls, indicating a worsened health outcome, albeit only at the 10% significance level (Table 26; Model 6-PrimaryEd;  $p < 0.100$ ). In contrast, no significant result was found in the secondary education subgroup (Table 26; Model 7-SecondEd;  $p > 1.000$ ). Mafirakureva et al. (2016) highlighted education as a determinant of HRQoL. Therefore, these findings could be highlighting the fact that those individuals lacking in education are unable to take advantage of the benefits of the trial, possibly due to a lack of literacy and learning opportunities.

Tables 28 and 29 present the results for the PopART trial impact on pain or discomfort (*Qolpain*). For most samples, the trial has no impact on the assessed outcomes with the exception of those with primary education, for which the trial increases treated *Qolpain* scores by 0.049 compared to controls, significant at the 5% level (Table 28; Model 6-PrimaryEd;  $p < 0.050$ ). Again, a positive coefficient is an indication of a worsened health state in the pain or discomfort domain. In contrast to the primary results, the results for the secondary schooling subgroup are not significant (Table 28; Model 7-SecondEd;  $p > 1.000$ ). Focusing on the last two HRQoL dimensions in Tables 30–33, anxiety or depression (*Qolanx*) and mobility (*Qolmob*), I find that the trial did not impact these HRQoL dimensions for any of the samples.

The three significant results mentioned above have been highlighted in bold in Tables 25, 26, and 28. In Appendix D, Table 58, a final robustness check assesses the dynamic effects of the trial in the different outcomes, where the policy effect is assessed by wave, confirming the lack of time effects in these findings.

**Table 22***Regression Results – Combined, Weighted Score (EQ5D)*

|                     | (1-BaseCase)      | (2-Females)       | (3-Males)         | (4-L.Wealth)      | (5-H.Wealth)      | (6-PrimaryEd)     | (7-SecondEd)      |
|---------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| post                | 0.004<br>(0.003)  | 0.004<br>(0.003)  | 0.003<br>(0.003)  | 0.005<br>(0.003)  | 0.003<br>(0.003)  | 0.008<br>(0.005)  | 0.003<br>(0.002)  |
| policy              | -0.005<br>(0.004) | -0.006<br>(0.004) | -0.002<br>(0.003) | -0.004<br>(0.004) | -0.006<br>(0.004) | -0.009<br>(0.005) | -0.004<br>(0.003) |
| wealth              | -0.000<br>(0.000) | -0.000<br>(0.001) | 0.000<br>(0.000)  |                   |                   | 0.000<br>(0.000)  | -0.000<br>(0.000) |
| working             | 0.001<br>(0.000)  | 0.001<br>(0.001)  | 0.000<br>(0.001)  | 0.001<br>(0.001)  | 0.001<br>(0.001)  | 0.002<br>(0.002)  | 0.001<br>(0.000)  |
| wave                | 0.001<br>(0.001)  | 0.001<br>(0.001)  | 0.001<br>(0.001)  | 0.001<br>(0.001)  | 0.001<br>(0.001)  | 0.003*<br>(0.001) | 0.001<br>(0.001)  |
| N                   | 102,329           | 72,950            | 29,379            | 55,511            | 46,818            | 15,054            | 87,275            |
| Individual Controls | yes               | yes               | yes               | yes               | yes               | yes               | yes               |
| Fixed Effects       | yes               | yes               | yes               | yes               | yes               | yes               | yes               |

Notes: \* $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . In the case of the stratified models, the key variable upon which the data were stratified was then excluded from the regression, as can be seen here in the wealth models.

**Table 23***Regression Results (Employment) – Combined, Weighted Score (EQ5D)*

|                     | (1-BaseCase)      | (2-Employed)      | (3-Unemployed)    | (4-Formal)         | (5-Informal)      |
|---------------------|-------------------|-------------------|-------------------|--------------------|-------------------|
| post                | 0.004<br>(0.002)  | 0.004<br>(0.003)  | 0.005*<br>(0.003) | 0.005*<br>(0.003)  | 0.005*<br>(0.002) |
| policy              | -0.003<br>(0.003) | -0.004<br>(0.003) | -0.002<br>(0.003) | -0.006*<br>(0.003) | 0.004<br>(0.003)  |
| wealth              | -0.000<br>(0.000) | -0.000<br>(0.000) | -0.000<br>(0.000) | -0.000<br>(0.001)  | -0.000<br>(0.000) |
| working             | 0.000<br>(0.001)  |                   |                   |                    |                   |
| wave                | 0.000<br>(0.000)  | 0.000<br>(0.000)  | 0.000<br>(0.000)  | 0.000<br>(0.000)   | 0.000<br>(0.000)  |
| N                   | 158,955           | 93,804            | 54,218            | 28,270             | 33,452            |
| Individual Controls | yes               | yes               | yes               | yes                | yes               |
| Fixed Effects       | yes               | yes               | yes               | yes                | yes               |

Notes: \* $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . In the case of the stratified models, the key variable upon which the data were stratified was then excluded from the regression, as can be seen here in the employment models.

**Table 24***Regression Results – Self-Care (Qolself)*

|                     | (1-BaseCase)      | (2-Females)       | (3-Males)         | (4-L.Wealth)        | (5-H.Wealth)      | (6-PrimaryEd)     | (7-SecondEd)        |
|---------------------|-------------------|-------------------|-------------------|---------------------|-------------------|-------------------|---------------------|
| post                | -0.013<br>(0.011) | -0.013<br>(0.012) | -0.014<br>(0.009) | -0.014<br>(0.010)   | -0.006<br>(0.012) | -0.029<br>(0.022) | -0.010<br>(0.009)   |
| policy              | 0.017<br>(0.013)  | 0.019<br>(0.013)  | 0.012<br>(0.012)  | 0.014<br>(0.011)    | 0.018<br>(0.015)  | 0.031<br>(0.023)  | 0.014<br>(0.011)    |
| wealth              | -0.000<br>(0.001) | -0.000<br>(0.002) | -0.001<br>(0.002) |                     |                   | -0.004<br>(0.002) | 0.000<br>(0.002)    |
| working             | -0.005<br>(0.002) | -0.005<br>(0.003) | -0.005<br>(0.002) | -0.004<br>(0.003)   | -0.006<br>(0.004) | -0.007<br>(0.009) | -0.005**<br>(0.002) |
| wave                | -0.003<br>(0.002) | -0.003<br>(0.002) | -0.002<br>(0.002) | -0.004**<br>(0.001) | -0.003<br>(0.003) | -0.005<br>(0.003) | -0.002<br>(0.001)   |
| N                   | 102,564           | 73,112            | 29,452            | 55,605              | 46,959            | 15,106            | 87,458              |
| Individual Controls | yes               | yes               | yes               | yes                 | yes               | yes               | yes                 |
| Fixed Effects       | yes               | yes               | yes               | yes                 | yes               | yes               | yes                 |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . In the case of the stratified models, the key variable upon which the data were stratified was then excluded from the regression, as can be seen here in the wealth models.

**Table 25***Regression Results (Employment) – Self-Care (Qolself)*

|                     | (1-BaseCase)      | (2-Employed)      | (3-Unemployed)    | (4-Formal)                        | (5-Informal)       |
|---------------------|-------------------|-------------------|-------------------|-----------------------------------|--------------------|
| post                | -0.013<br>(0.011) | -0.010<br>(0.012) | -0.014<br>(0.010) | -0.017**<br>(0.006)               | 0.009<br>(0.012)   |
| policy              | 0.017<br>(0.013)  | 0.017<br>(0.013)  | 0.013<br>(0.011)  | <b>0.018*</b><br>( <b>0.008</b> ) | -0.008<br>(0.010)  |
| wealth              | -0.000<br>(0.001) | -0.001<br>(0.001) | -0.000<br>(0.002) | 0.000<br>(0.001)                  | 0.004<br>(0.002)   |
| working             | -0.005<br>(0.002) |                   |                   |                                   |                    |
| wave                | -0.003<br>(0.002) | -0.004<br>(0.003) | -0.002<br>(0.002) | -0.002<br>(0.003)                 | -0.005*<br>(0.002) |
| N                   | 102,564           | 64,644            | 37,920            | 19,759                            | 18,063             |
| Individual Controls | yes               | yes               | yes               | yes                               | yes                |
| Fixed Effects       | yes               | yes               | yes               | yes                               | yes                |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . In the case of the stratified models, the key variable upon which the data were stratified was then excluded from the regression, as can be seen here in the employment models.

**Table 26**  
*Regression Results – Usual Activities (Qolact)*

|                     | (1-BaseCase)        | (2-Females)       | (3-Males)          | (4-L.Wealth)      | (5-H.Wealth)       | (6-PrimaryEd)                   | (7-SecondEd)        |
|---------------------|---------------------|-------------------|--------------------|-------------------|--------------------|---------------------------------|---------------------|
| post                | -0.013<br>(0.011)   | -0.016<br>(0.013) | -0.007<br>(0.010)  | -0.018<br>(0.012) | -0.001<br>(0.011)  | -0.034<br>(0.023)               | -0.009<br>(0.009)   |
| policy              | 0.023<br>(0.015)    | 0.029<br>(0.016)  | 0.007<br>(0.014)   | 0.020<br>(0.015)  | 0.021<br>(0.015)   | <b>0.056*</b><br><b>(0.023)</b> | 0.017<br>(0.014)    |
| wealth              | -0.000<br>(0.002)   | 0.000<br>(0.002)  | -0.002<br>(0.002)  |                   |                    | -0.002<br>(0.004)               | -0.000<br>(0.002)   |
| working             | -0.006**<br>(0.002) | -0.005<br>(0.003) | -0.009*<br>(0.004) | -0.007<br>(0.004) | -0.005*<br>(0.002) | -0.010<br>(0.007)               | -0.005**<br>(0.002) |
| wave                | -0.005<br>(0.003)   | -0.005<br>(0.003) | -0.005*<br>(0.002) | -0.004<br>(0.003) | -0.005<br>(0.004)  | -0.013*<br>(0.006)              | -0.004<br>(0.003)   |
| N                   | 102,550             | 73,107            | 29,443             | 55,603            | 46,947             | 15,102                          | 87,448              |
| Individual Controls | yes                 | yes               | yes                | yes               | yes                | yes                             | yes                 |
| Fixed Effects       | yes                 | yes               | yes                | yes               | yes                | yes                             | yes                 |

Notes: \* $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . In the case of the stratified models, the key variable upon which the data were stratified was then excluded from the regression, as can be seen here in the wealth models.

**Table 27**  
*Regression Results (Employment) – Usual Activities (Qolact)*

|                     | (1-BaseCase)        | (2-Employed)      | (3-Unemployed)    | (4-Formal)         | (5-Informal)      |
|---------------------|---------------------|-------------------|-------------------|--------------------|-------------------|
| post                | -0.013<br>(0.011)   | -0.013<br>(0.013) | -0.014<br>(0.010) | -0.012*<br>(0.005) | -0.001<br>(0.011) |
| policy              | 0.023<br>(0.015)    | 0.026<br>(0.015)  | 0.015<br>(0.013)  | 0.011<br>(0.011)   | 0.001<br>(0.017)  |
| wealth              | -0.000<br>(0.002)   | -0.002<br>(0.002) | -0.000<br>(0.003) | 0.001<br>(0.004)   | -0.002<br>(0.001) |
| working             | -0.006**<br>(0.002) |                   |                   |                    |                   |
| wave                | -0.005<br>(0.003)   | -0.006<br>(0.003) | -0.002<br>(0.003) | -0.001<br>(0.004)  | -0.006<br>(0.005) |
| N                   | 102,550             | 64,634            | 37,916            | 19,758             | 18,060            |
| Individual Controls | yes                 | yes               | yes               | yes                | yes               |
| Fixed Effects       | yes                 | yes               | yes               | yes                | yes               |

Notes: \* $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . In the case of the stratified models, the key variable upon which the data were stratified was then excluded from the regression, as can be seen here in the employment models.

**Table 28***Regression Results – Pain or Discomfort (Qolpain)*

|                     | (1-BaseCase)      | (2-Females)       | (3-Males)         | (4-L.Wealth)      | (5-H.Wealth)      | (6-PrimaryEd)             | (7-SecondEd)      |
|---------------------|-------------------|-------------------|-------------------|-------------------|-------------------|---------------------------|-------------------|
| post                | -0.010<br>(0.023) | -0.016<br>(0.026) | 0.002<br>(0.021)  | -0.010<br>(0.031) | -0.011<br>(0.022) | -0.038<br>(0.030)         | -0.005<br>(0.022) |
| policy              | 0.026<br>(0.022)  | 0.037<br>(0.026)  | -0.003<br>(0.016) | 0.020<br>(0.027)  | 0.044<br>(0.023)  | <b>0.049**</b><br>(0.013) | 0.020<br>(0.024)  |
| wealth              | 0.005<br>(0.004)  | 0.008<br>(0.005)  | 0.000<br>(0.004)  |                   |                   | 0.001<br>(0.004)          | 0.006<br>(0.004)  |
| working             | -0.000<br>(0.005) | -0.004<br>(0.005) | 0.007<br>(0.009)  | 0.000<br>(0.007)  | -0.003<br>(0.005) | -0.013<br>(0.007)         | 0.002<br>(0.006)  |
| wave                | -0.012<br>(0.009) | -0.013<br>(0.009) | -0.008<br>(0.009) | -0.011<br>(0.007) | -0.013<br>(0.013) | -0.024*<br>(0.012)        | -0.010<br>(0.008) |
| N                   | 102,546           | 73,102            | 29,444            | 55,603            | 46,943            | 15,100                    | 87,446            |
| Individual Controls | yes               | yes               | yes               | yes               | yes               | yes                       | yes               |
| Fixed Effects       | yes               | yes               | yes               | yes               | yes               | yes                       | yes               |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . In the case of the stratified models, the key variable upon which the data were stratified was then excluded from the regression, as can be seen here in the wealth models.

**Table 29***Regression Results (Employment) – Pain or Discomfort (Qolpain)*

|                     | (1-BaseCase)      | (2-Employed)      | (3-Unemployed)    | (4-Formal)        | (5-Informal)      |
|---------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| post                | -0.010<br>(0.023) | -0.006<br>(0.026) | -0.025<br>(0.023) | -0.007<br>(0.019) | -0.051<br>(0.026) |
| policy              | 0.026<br>(0.022)  | 0.030<br>(0.023)  | 0.023<br>(0.020)  | 0.026<br>(0.024)  | 0.022<br>(0.025)  |
| wealth              | 0.005<br>(0.004)  | 0.006<br>(0.004)  | 0.003<br>(0.004)  | 0.004<br>(0.006)  | -0.001<br>(0.006) |
| working             | -0.000<br>(0.005) |                   |                   |                   |                   |
| wave                | -0.012<br>(0.009) | -0.015<br>(0.010) | -0.007<br>(0.008) | -0.005<br>(0.008) | -0.013<br>(0.010) |
| N                   | 102,546           | 64,627            | 37,919            | 19,757            | 18,064            |
| Individual Controls | yes               | yes               | yes               | yes               | yes               |
| Fixed Effects       | yes               | yes               | yes               | yes               | yes               |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . In the case of the stratified models, the key variable upon which the data were stratified was then excluded from the regression, as can be seen here in the employment models.

**Table 30***Regression Results – Anxiety or Depression (Qolanx)*

|                     | (1-BaseCase) | (2-Females) | (3-Males) | (4-L.Wealth) | (5-H.Wealth) | (6-PrimaryEd) | (7-SecondEd) |
|---------------------|--------------|-------------|-----------|--------------|--------------|---------------|--------------|
| post                | -0.045*      | -0.050*     | -0.034    | -0.058**     | -0.029       | -0.053        | -0.043**     |
|                     | (0.019)      | (0.020)     | (0.020)   | (0.018)      | (0.031)      | (0.038)       | (0.016)      |
| policy              | 0.029        | 0.037       | 0.011     | 0.024        | 0.035        | 0.037         | 0.027        |
|                     | (0.040)      | (0.043)     | (0.035)   | (0.038)      | (0.046)      | (0.058)       | (0.038)      |
| wealth              | 0.001        | 0.001       | -0.001    |              |              | -0.002        | 0.001        |
|                     | (0.004)      | (0.004)     | (0.003)   |              |              | (0.003)       | (0.004)      |
| working             | -0.008*      | -0.009*     | -0.004    | -0.011*      | -0.005       | -0.005        | -0.008*      |
|                     | (0.004)      | (0.004)     | (0.006)   | (0.005)      | (0.004)      | (0.007)       | (0.004)      |
| wave                | 0.000        | 0.000       | -0.001    | 0.001        | 0.002        | -0.012        | 0.002        |
|                     | (0.007)      | (0.007)     | (0.006)   | (0.006)      | (0.009)      | (0.009)       | (0.006)      |
| N                   | 102,508      | 73,074      | 29,434    | 55,594       | 46,914       | 15,087        | 87,421       |
| Individual Controls | yes          | yes         | yes       | yes          | yes          | yes           | yes          |
| Fixed Effects       | yes          | yes         | yes       | yes          | yes          | yes           | yes          |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . In the case of the stratified models, the key variable upon which the data were stratified was then excluded from the regression, as can be seen here in the wealth models.

**Table 31***Regression Results (Employment) – Anxiety or Depression (Qolanx)*

|                     | (1-BaseCase) | (2-Employed) | (3-Unemployed) | (4-Formal) | (5-Informal) |
|---------------------|--------------|--------------|----------------|------------|--------------|
| post                | -0.045*      | -0.054**     | -0.040         | -0.052     | -0.018       |
|                     | (0.019)      | (0.017)      | (0.022)        | (0.026)    | (0.031)      |
| policy              | 0.029        | 0.042        | 0.011          | 0.038      | -0.059       |
|                     | (0.040)      | (0.037)      | (0.048)        | (0.046)    | (0.085)      |
| wealth              | 0.001        | -0.000       | -0.001         | 0.001      | -0.006       |
|                     | (0.004)      | (0.004)      | (0.006)        | (0.006)    | (0.008)      |
| working             | -0.008*      |              |                |            |              |
|                     | (0.004)      |              |                |            |              |
| wave                | 0.000        | 0.002        | 0.000          | 0.004      | -0.003       |
|                     | (0.007)      | (0.008)      | (0.006)        | (0.007)    | (0.008)      |
| N                   | 102,508      | 64,602       | 37,906         | 19,753     | 18,055       |
| Individual Controls | yes          | yes          | yes            | yes        | yes          |
| Fixed Effects       | yes          | yes          | yes            | yes        | yes          |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . In the case of the stratified models, the key variable upon which the data were stratified was then excluded from the regression, as can be seen here in the employment models.

**Table 32***Regression Results – Mobility (Qolmob)*

|                     | (1-BaseCase)       | (2-Females)          | (3-Males)         | (4-L.Wealth)      | (5-H.Wealth)      | (6-PrimaryEd)        | (7-SecondEd)      |
|---------------------|--------------------|----------------------|-------------------|-------------------|-------------------|----------------------|-------------------|
| post                | -0.008<br>(0.011)  | -0.006<br>(0.012)    | -0.014<br>(0.010) | -0.012<br>(0.010) | 0.003<br>(0.013)  | -0.010<br>(0.019)    | -0.008<br>(0.009) |
| policy              | 0.019<br>(0.011)   | 0.022<br>(0.012)     | 0.011<br>(0.011)  | 0.012<br>(0.012)  | 0.019<br>(0.013)  | 0.033<br>(0.020)     | 0.016<br>(0.010)  |
| wealth              | -0.000<br>(0.001)  | 0.000<br>(0.001)     | -0.001<br>(0.002) |                   |                   | -0.005<br>(0.003)    | 0.001<br>(0.001)  |
| working             | -0.003*<br>(0.001) | -0.006***<br>(0.001) | 0.004<br>(0.005)  | -0.003<br>(0.002) | -0.003<br>(0.003) | -0.007***<br>(0.001) | -0.002<br>(0.001) |
| wave                | -0.004<br>(0.003)  | -0.005<br>(0.004)    | -0.002<br>(0.002) | -0.004<br>(0.003) | -0.003<br>(0.005) | -0.013**<br>(0.005)  | -0.003<br>(0.003) |
| N                   | 102,467            | 73,048               | 29,419            | 55,549            | 46,918            | 15,091               | 87,376            |
| Individual Controls | yes                | yes                  | yes               | yes               | yes               | yes                  | yes               |
| Fixed Effects       | yes                | yes                  | yes               | yes               | yes               | yes                  | yes               |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . In the case of the stratified models, the key variable upon which the data were stratified was then excluded from the regression, as can be seen here in the wealth models.

**Table 33***Regression Results (Employment) – Mobility (Qolmob)*

|                     | (1-BaseCase)       | (2-Employed)      | (3-Unemployed)    | (4-Formal)        | (5-Informal)      |
|---------------------|--------------------|-------------------|-------------------|-------------------|-------------------|
| post                | -0.008<br>(0.011)  | -0.003<br>(0.012) | -0.011<br>(0.010) | -0.021<br>(0.014) | 0.018<br>(0.010)  |
| policy              | 0.019<br>(0.011)   | 0.018<br>(0.012)  | 0.008<br>(0.010)  | 0.020<br>(0.017)  | -0.026<br>(0.014) |
| wealth              | -0.000<br>(0.001)  | -0.001<br>(0.002) | 0.000<br>(0.002)  | 0.000<br>(0.003)  | 0.002<br>(0.004)  |
| working             | -0.003*<br>(0.001) |                   |                   |                   |                   |
| wave                | -0.004<br>(0.003)  | -0.006<br>(0.004) | -0.003<br>(0.003) | -0.002<br>(0.003) | -0.006<br>(0.004) |
| N                   | 102,467            | 64,581            | 37,886            | 19,740            | 18,049            |
| Individual Controls | yes                | yes               | yes               | yes               | yes               |
| Fixed Effects       | yes                | yes               | yes               | yes               | yes               |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . In the case of the stratified models, the key variable upon which the data were stratified was then excluded from the regression, as can be seen here in the employment models.

## 4.6 Discussion

This study utilises 18 of the 21 communities of the PopART study, examining the impact of the trial on health-related quality of life. I also examine the heterogeneity of those effects by sex, wealth, education, and a variety of employment subgroups, including the unemployed and employed, and formal and informal employment. I examine the impact of the trial on all five key domains of the HRQoL index, namely self-care, usual activities, pain or discomfort, anxiety or depression, and mobility. In addition, I built an overall quality of life index that is a combination of the five domains.

Results show that the trial had a negative and statistically significant impact on self-care in the treated, formally employed subgroups. While I do not investigate the mechanisms for these effects, individuals employed formally perhaps feel diminished in their work environment by a positive diagnosis, whereas the informally employed do not. It is possible that formal workers may have more designated positions, and less flexibility to take time off to seek treatment as needed, or they may fear that their work environments would not be supportive (Honiden et al., 2006). These findings are unique and expand upon the work that has been done on the EQ-5D-5L, which so far has not found connections in employment sufficiently granular to explore formal vs informal employment in the context of assessing HRQoL outcomes in SSA.

My results show a statistically significant positive effect of the PopART intervention on the pain or discomfort (Qolpain) domain of the HRQoL. This contrasts with the finding for the impact of the trial on pain or discomfort in PLHIV in the paper by Davis et al. (2022). The finding by Davis et al. (2022) is an average effect across the entire sample. What I find is heterogeneity of effects by population subgroup. If one was to look at the trial's average effects, as Davis et al. (2022) have done, then these effects may cancel out. Therefore, the two studies do not have inconsistent findings. Additionally, a true comparison with the findings in the Davis et al. (2022) paper cannot be made as we used different criteria for inclusion into the sample based on HIV status. My analysis excludes one triplet as there was an anomaly, discussed in Chapter 3, in relation to abnormal healthcare utilisation in some of the communities due to a cholera outbreak. Davis et al. (2022) did not focus on healthcare utilisation, so they had no need to exclude this triplet.

The trial had a negative, significant impact on treated individuals with lower education. This is consistent with the broader literature on HRQoL in LMICs, which indicates that those that are less educated typically lag behind those with a higher level of education in HRQoL scores and in health literacy (Degroote et al., 2014; Hallman, 2005; Jung et al., 2013; Wawrzyniak et al., 2013). My findings support the work of Friend-du Preez and Peltzer (2010), which shows, particularly in South Africa, that those individuals living with HIV are often the most susceptible to a poor quality of life when they lack higher education. Lastly, my final finding is in the area of usual activities (*QoLact*). I again find a negative, significant impact on HRQoL for treated individuals with lower levels of education. These findings are unique in their heterogeneous nature, demonstrating that specific subgroups were impacted most by the trial.

Thanks to the individual-level data available from the PopART trial, I was able to examine granular subgroups in all my analyses. There are, of course, limitations, as with any quantitative analysis. There were very few significant findings. Women are significantly over-represented in the PopART data, perhaps due to the fact the questionnaire was given during the day when more men may have been at work, which could have caused sex and employment results to not be entirely representative of the total population (Hayes et al., 2019). One potential remedy for this would be to conduct the survey during a rest period, when both males and females are equally likely to be at home and not out at work, or, for example, preparing dinner. A disadvantage of this is that this would likely involve more expenses for those conducting the survey if they were conducting it in traditional out-of-work hours. Also, I assess here only the subgroup outcomes and do not make a full assessment of the potential mechanisms driving these outcomes.

Under-enumeration of the male subgroup is an issue of sample selection, potentially leading to biased inferences (Winship & Mare, 1992). This occurs when participants are selected such that they are not independent of the outcome variable in the study. As explained above, it might be the case that males who were at work when the survey interviews were conducted were less likely to be included in this study than other males. If so, this would mean that I am not observing a random sample of the population of interest and my findings on HRQoL could be biased if there is an association between employment and level of well-being. This bias, in turn, could lead to under- or overestimation in the results (Stenholm et al., 2007; Winship & Mare, 1992). If I assume that males who work out

of the home – and therefore are less likely to be included in the sample – are generally more healthy than other males, then, other things being equal, the results presented here would overstate any negative findings due to the trial.

In Table 22, the overall HRQoL scores, you can see that the direction of Policy on the male subgroup is consistent with the rest of the subgroups, indicating an insignificant, yet beneficial result of the trial on the treated individuals' HRQoL. With the under-reporting of the males in the population, it does raise the question of the accuracy of this result. Note that in this table there are fewer than 30,000 men, as compared to almost 73,000 women. This is the case (insignificant, yet consistent directional impact) for all five of the component variables that make up the EQ5D summary variable, with the exception of pain and discomfort, as demonstrated in Table 28. Here, only males are shown to have a positive result from the trial, however insignificant, differing from the other subgroups. I was unable to stratify by sex in the employment models, due to the low observation count on males. It is possible that this pain or discomfort result is picking up some employment results for the males, but it is impossible to know for sure without further data.

Additionally, there was no Zambian version of the questionnaire, specifically in the HRQoL questions, which was difficult to translate into the local dialect (Rabin et al., 2014). The EQ- 5D-5L is a broad instrument, not specifically tailored to an HIV population, and thus may not be sensitive to changes in quality of life in response to treatment and support. It has certainly now become more common to apply country-specific value sets to the EQ-5D-5L. With no country-specific value weights, even if I am not able to differentiate among the countries in SSA, the utilities derived from the HRQoL scores (unique to each country) would help relate things to the general area. Unfortunately, in SSA, these are not available, except for Zimbabwe. In response, I applied Zimbabwean utility weights to the data, as has become a more common practice (Gerlinger et al., 2019). As Gerlinger et al. (2019) note, if I were not to apply the Zimbabwean weights to my data, I would be overestimating the scores in mobility, pain/discomfort, and anxiety/depression, and underestimating the scores in self- care and usual activities, in relation to high-income countries. Additionally, the EQ-5D-5L does not capture stigma, which is a further limitation. Furthermore, the EQ-5D-EL does not capture any differences among disease stages for HIV-infected individuals, nor do I have comprehensive data on multi-morbidities of the study participants. It would be sensible to assume that HRQoL would be lower as an HIV-infected individual's disease

stage advances, or they develop any co-morbidities, but unfortunately I do not have such data.

One further limitation is something I will call the “disentangling” effect. As one individual was surveyed per household, although the difference-in-differences approach does allow for causal inference of the impact of the trial on the individual, it is impossible to account for the impact of intra-household effects when the linkages within households to HIV-infected individuals are not known. For example, if there is an HIV-infected individual in the household who is not surveyed, and who is improving due to the effects of the trial, this may have a spillover effect on a surveyed HIV-negative individual who responds to the survey on their own HRQoL. It is possible, indeed perhaps likely, that my results were more conservative as a result of including both HIV-infected and -uninfected individuals in the analysis; however, I view this as the true overall impact of the trial, due to these unseen linkages.

This paper demonstrates causal, significant impacts of the PopART trial on HRQoL, using the EQ-5D-5L questionnaire. As further test and treat trials are rolled out, this is useful, informative knowledge in continuing with the inclusion of such HRQoL measures and in further assessing the impact on various subgroups. Interventions such as the PopART trial should, and will, continue to play a role in international health policies going forward, for years to come.

Much more attention has been shed on HRQoL recently, especially with the UNAIDS’ proposed, although ultimately not adopted, “fourth 90” – aimed at ensuring that 90% of people with viral load have good HRQoL. These are meaningful findings, as better understanding the reach of a trial will help inform future policies that may be adjacent to further test and treat trials, and that may hopefully offer additional HRQoL benefits. In conclusion, there is a fascinating opportunity to consider the impact of policy implications that a test and treat trial may have on HRQoL, even as a secondary impact of the intervention goal to reduce incidence.

## **5 Chapter 5: Concluding Remarks**

### **5.1 Research Summary**

The purpose of this thesis has been to shed light on the serious economic impacts of HIV, which may have been overlooked due to the massive health consequences of the disease. A total of 36.3 million individuals have lost their lives to AIDS-related illnesses, and 79.3 million individuals have become infected with HIV since the beginning of the epidemic (UNAIDS, 2021c). However, today, HIV has become a manageable disease, with near-normal life expectancy (Basavaraj et al., 2010; Kharsany & Karim, 2016), but not without economic costs. HIV is not a disease that impacts individuals uniformly. There are major reductions in the working age population due to HIV in Sub-Saharan Africa (Kharsany & Karim, 2016). There are pro-rich inequities in access to primary healthcare, which mirrors the same issues found in high-income countries (Van Doorslaer & Wagstaff, 1992; Van Doorslaer et al., 2000), and there is subgroup heterogeneity in certain populations that remain less receptive to test and treat interventions, which are being more broadly rolled out today (Havlir et al., 2020; Hayes et al., 2014; Perriat et al., 2018). Thus, policymakers need careful estimates of the macroeconomic impacts of HIV, as well as a thorough understanding of which populations the HIV burden is falling upon. Fortunately, we have economic tools for measuring these issues, which is what I have hoped to capture in this thesis.

In Chapter 2, I focused on the impact of HIV on economic activity, specifically examining the causal impact of HIV prevalence on gold production in SSA. My results show that HIV prevalence is associated with a decrease in gold production, with a 1% increase in HIV prevalence resulting in a production loss of gold valued at approximately USD 118 million, based on the average LBMA gold price in 2017 (LBMA, 2018), significant at the 10% level. This is approximately a 7% average annual decrease in the mean GDP per capita of the sample (WDI, 2017). This is a meaningful finding on the magnitude of the effect of the damage that HIV has on economic activity over an extended period of time. In Chapter 3, I explored the impact of the PopART trial on distributional inequity in Zambia and South Africa. I find a pro-rich inequity in healthcare utilisation, as ranked by wealth. This means, for example, that the 20% poorest make up less than 20% of the access to healthcare, and I find that this pro-rich bias significantly increased after the PopART trial was initiated. Lastly, in Chapter 4, I continued to work with the PopART data, assessing the

impact of the trial on HRQoL, and the extent to which it varies across sex, wealth, education, and employment status. Specifically, a significant result in the HRQoL dimension of Usual Activities is found in the primary-level-educated subgroup, lowering the health state scores in this dimension in treated individuals, as compared to individuals in the control arm. Additionally, in the Self-Care dimension, I find lowered scoring in the treated individuals as compared to those in the control arm in the formally employed subgroup.

Lastly, a significant result in the HRQoL dimension of Pain or Discomfort was also found for the primary-level-educated subgroup, indicating that the treated subgroup was experiencing more pain or discomfort than the control group. The CHiPs were local health workers who were recruited in all communities (Stangl et al., 2020). Thus, it is possible that there was a slight reduction in the outside local services offered. Even if this was not the case, a shift in the way services were offered would have been the case. One of the hallmarks of less-educated individuals is having less “health literacy”, according to Degroote et al. (2014), Hallman (2005), Jung et al. (2013), and Wawrzyniak et al. (2013). Thus, it is plausible that in not understanding where to reach out for care, pain, and discomfort, perhaps due to minor injuries or ailments, would have increased in this population. Ultimately, these results indicate that the PopART trial, while successful in reducing the population-level incidence of HIV infection (Hayes et al., 2019), as was its primary goal, did have other impacts as well, which have been captured in this thesis with econometric methods.

There are numerous strengths and contributions in this thesis. For example, in Chapter 2, I am able to capture the causal impact of HIV-related productivity losses on economic output at the macroeconomic level. I utilise an Arellano-Bond estimator to capture the causal impact of HIV on gold production. Prior to my study, the research in this area has focused on firm-level productivity losses due to HIV, most specifically focused on individual absenteeism and days of work lost due to illness (Fox et al., 2004; Guinness et al., 2003; Habyarimana et al., 2010; Larson et al., 2008, 2009; Matangi, 2006; Murray et al., 2005; Rosen et al., 2004; Simon et al., 2000; Sonnenberg et al., 2011). My analysis enables a grossed-up comparison, allowing for a by-country comparison, and an estimate of the total GDP lost due to the impact of HIV on productivity. Chapter 2 also addresses firm-level contributions to treating HIV. Chapters 3 and 4 extend this topic to the study of data from the PopART trial, a universal test and treat

trial. In Chapter 3, I estimate inequity in healthcare utilisation. Most of the research in LMICs does not cover inequities but instead focuses on the simpler methodology of distributional imbalances (Barrenho et al., 2019; Ngandu et al., 2017; Yourkavitch et al., 2018). I go beyond this work using concrete methodologies of concentration curves, concentration indices, and the health inequity index. In addition, I am the first to make use of RCT data to implement these methods. In Chapter 4, I build on my work utilising the PopART data. Similarly to Davis et al. (2022), I assess the average impact of the trial on HRQoL, as well as the different dimensions of the HRQoL index. However, my work offers some significant contributions. I deploy an advanced methodology, utilising difference-in-differences methodologies to better identify the impact of the trial. An additional key contribution of this study is that I assess the heterogeneity of trial effects across sex, wealth, education, and employment type, which has not been done before in an HIV trial setting.

## **5.2 Policy Implications & Scope for Future Research**

The findings of this thesis have many implications for policymakers, firms, and the broader economy. The first was revealed in Chapter 2, which has provided concrete evidence that it is critical to invest in health to avoid economic losses. HIV is a unique disease in that it largely impacts individuals in their prime working years (Kharsany & Karim, 2016). Thus, better health also translates into economic gains, as treatment enables people living with HIV to remain employed and maintain full productivity. Additionally, better health for parents implies better access to education for their children, as they are not required to take on a caretaking position (Bor et al., 2012; Coombe, 2000). People initiating treatment early, before the onset of any AIDS-related symptoms, avoid steep productivity losses and are often able to evade lengthy periods of unemployment altogether (Bor et al., 2012). There is also a strong argument for a change in policy regarding the treatment of TB in the gold mining industry, as TB transmission is considered to be a hot spot in gold mines (Chang et al., 2018), and recurrent TB occurs more commonly in HIV-infected patients (Sterling et al., 1999). From a macroeconomic perspective, Kharsany and Karim (2016) state that the main consequence of HIV is a reduction in the growth of the working age population. Kharsany and Karim (2016) take this point further. The authors state that in some countries with a higher prevalence, the working population is 10% smaller than it would have been in the absence of HIV. Especially in an industry such as gold mining, where there are large costs associated with training and replacement, workers are not easily substitutable (Matangi, 2006). In summary, the investments (or interventions) in ART drive reductions in HIV transmission (Attia et al., 2009; Donnell et al., 2010; Granich et al., 2009), which will then slow HIV transmission, which in turn limits the damage that HIV-related losses in productivity do to economic output (Haacker, 2002; Piot et al., 2001; Rosen et al., 2000). As can be seen in Chapter 2, these losses then carry through to the overall economy in the form of a smaller GDP, which is why investment in health is economically beneficial.

Additionally, the results of my work on inequalities and inequities in Chapter 3 bring to light further policy suggestions for the HIV community. For example, my findings indicated a pro-rich inequity in access to primary healthcare, implying that those at a greater socio-economic disadvantage are not receiving the access to care they need, in alignment with

their HIV health burden. This is a form of discrimination. Stigma, discrimination, and health inequalities create barriers to access to testing, prevention, and care (HIV Commission, 2022). Blockages to testing imply later diagnoses, and possibly an increase in transmission rates before an individual is on treatment. It is imperative that stigma and health inequalities be addressed in any treatment and prevention initiatives so that there are no key populations missed. The UNAIDS goal to end AIDS by 2030 addresses inequalities as well, as a way to end social, economic, racial, and gender barriers that perpetuate the HIV pandemic (UNAIDS, 2021a). The data found in my research adds to the evidence supporting these initiatives.

As the prognosis for those infected with HIV has improved, there has been a large policy focus on the well-being of PLHIV as they age. HIV-positive individuals on ART are living into their sixties, and beyond. HIV-related mortality is significantly falling. There has been a 64% reduction since the peak in 2004, and a 47% reduction since 2010 (UNAIDS, 2021c). However, despite living longer lives, PLHIV are prone to multiple co-morbidities that may lower their quality of life (Costagliola, 2014; Kooij et al., 2016; Schouten et al., 2014, 2016). In addition, many individuals need pain management or suffer from mental health complications (Lazarus et al., 2016), or stigma and discrimination, all of which may impact quality of life and, in turn, possibly affect treatment adherence (Scofield & Moseholm, 2022). The need to improve HRQoL is particularly relevant for SSA given the significantly higher prevalence of HIV in the region, combined with an ageing population (Aboderin, 2012; UNDP, 2012) and rampant inequalities. There is empirical evidence linking lowered HRQoL with “social inequalities”, and the impact that inequalities and a low quality of life can have on employment and food security (Nigusso & Mavhandu-Mudzusi, 2021). Lazarus et al. (2016) proposed a new goal, the “fourth UNAIDS 90”, intended to ensure good HRQoL for PLHIV, including in regard to an individual’s self-perceived quality of life, or any co-morbidities they may have. Although the motion was not ultimately included as an official UNAIDS policy goal, the concept of HRQoL is one that demands a great deal of attention. My findings in this area, as laid out in Chapter 4, were surprising. I researched population subgroups, and my results indicated that during the period immediately following the initiation of the trial, the subgroup of treated individuals formally employed, and the subgroup of treated individuals with less education, suffered with respect to HRQoL compared to those in the control arm of the trial. It is possible that these individuals were

more susceptible to self-stigma in response to discovering their HIV status. However, as UTT trials continue to be rolled out, it is imperative that considerations for subgroups are well considered. Perhaps initiatives such as treatment options being accessible outside normal working hours are important, as this may impact those who are formally employed. Additionally, focusing on HIV literacy is imperative, so that those individuals with less education may take advantage of all that a UTT intervention has to offer.

My research also highlights other potential areas for further research. The first is to expand the macroeconomic research in Chapter 2 to identify other industries that have a high HIV prevalence in the workforce in order to gain a broader understanding of the full macroeconomic impact of HIV on economic output. Another way to expand Chapter 2 would be to focus more on the impact of private, corporate-provided HIV treatment, and how such care impacts the health and productivity of the workforce. Unfortunately, I do not have the data to measure losses in productivity directly through absenteeism or presenteeism. As discussions occur to drive workplace initiatives to promote well-being, it is key to assess the Sustainable Development Goals (SDGs), such as Goal 3, to “Ensure healthy lives and promote well-being for all at all ages” (United Nations, 2015). There is a double value in that employers can be active in promoting health, but it is also strategic for their economic performance.

In Chapter 3, we examine inequalities and inequities at the community level. I did not have this level of granularity in the PopART data, but it would be useful to understand the relationship between inequalities and inequities and healthcare utilisation at the individual and household level, should data be available that would make this possible. With such data, I could link healthcare utilisation to the health status of other family members in the household, shedding more light on why people may or may not utilise formal healthcare. Additionally, in Chapter 3, I utilised wealth as my socio-economic ranking variable. This analysis could be expanded to compare outcomes if the analysis were ranked by education or income. In Chapter 4, the EQ-5D-5L is not the best tool for estimating HRQoL in SSA, as is evidenced by the skewed distribution of the results. It would be more useful to have a tool that matched the local dialect and community culture as to how they refer to their daily activities, mobility, etc., specific to HIV. Furthermore, the EQ-5D-5L does not capture stigma. As previously discussed, there is a differential gender prevalence of stigma, which may impact access to care.

Additionally, it is difficult to assess the impact on HRQoL with only four waves of data so close together. Individuals may experience an initial drop in HRQoL in response to a diagnosis (Kagee & Martin, 2010; Olley et al., 2004; Reynolds et al., 2009) that is captured in the PopART data, but we are not able to see the rise in HRQoL that we would expect from the positive increases in health after some years on ART (Beard et al., 2009; Peltzer & Phaswana-Mafuya, 2008). Lastly, the analyses in Chapter 3 and Chapter 4 could be run on additional UTT trials to confirm my findings, such as the SEARCH trial in East Africa (Havlir et al., 2019) or the Ya Tsie trial in Botswana (Makhema et al., 2019).

The findings in this thesis have provided unique contributions to the existing base of knowledge on the economics of HIV. Through this research we have learned about workforce productivity losses, country-level economic forfeiture, and loss of GDP. We have learned about a variety of interventions set in place to combat the disease, starting with suppression, including prevention, treatment, care, and more recently focusing on quality of life. We have focused on the inequity of access to this care, and which population subgroups suffer most in terms of quality of life. Lastly, I have suggested policy implications and possible future research expansions.

## 6 References

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## **7 Appendices**

### **7.1 Appendix A: Additional Data, Methods, and Results for Chapter 2**

*All tables on the following pages are referred to within the document.*

**Table 34***Summary Regression Results (Reduced Covariates)*

|                   | (OLS-1)           | (OLS-2)           | (A-B1)              | (A-B2)              |
|-------------------|-------------------|-------------------|---------------------|---------------------|
| hiv               | -8.719<br>(5.925) | -8.605<br>(5.197) | -2.171<br>(1.356)   | -2.473*<br>(1.467)  |
| L.gold            |                   |                   | 0.658***<br>(0.088) | 0.627***<br>(0.086) |
| autocracy         |                   | 0.490<br>(0.970)  | -0.684**<br>(0.295) | -0.727**<br>(0.303) |
| democracy         |                   | 0.627<br>(1.025)  | -0.362**<br>(0.175) | -0.495**<br>(0.193) |
| open              |                   | 0.194<br>(0.155)  | -0.047<br>(0.035)   | -0.024<br>(0.023)   |
| unemployment      |                   | 2.894<br>(1.843)  | 0.632<br>(0.584)    | 1.039*<br>(0.630)   |
| telinfrastructure |                   | 3.332<br>(2.849)  | 0.841<br>(0.517)    | 0.736<br>(0.456)    |
| primary           |                   | 0.237<br>(0.162)  | 0.041<br>(0.046)    | 0.038<br>(0.051)    |
| gdpcap            |                   | -0.002<br>(0.002) | -0.000<br>(0.001)   | -0.000<br>(0.001)   |
| migcap            |                   | -0.019<br>(0.069) | 0.003<br>(0.018)    | -0.001<br>(0.015)   |
| Time FE           | yes               | yes               | yes                 | yes                 |
| Country FE        | yes               | yes               | yes                 | yes                 |
| AR1 z-stat        |                   |                   | 0.035               | 0.032               |
| AR2 z-stat        |                   |                   | 0.137               | 0.139               |
| Hansen p-value    |                   |                   | 1.000               | 1.000               |
| Instrument count  |                   |                   | 212                 | 152                 |
| N                 | 808               | 808               | 678                 | 678                 |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Robust standard errors in parentheses. The dependent variable is gold production in all columns. The Arellano-Bond model is a GMM estimator with country clustered robust standard errors. In all models lagged gold production is predetermined, HIV is endogenous, and are collapsed to create one instrument for each variable and lag distance. A-B1 limits lags to eight years. A-B2 limits lags to five years. Consumption and countrysize have been eliminated as covariates.

**Table 35***Regression Results – Stepwise (Reduced Covariates)*

| <b>Dependent Variable: Gold Production</b> |          |          |          |           |          |          |          |          |          |
|--------------------------------------------|----------|----------|----------|-----------|----------|----------|----------|----------|----------|
|                                            | (M1)     | (M2)     | (M3)     | (M4)      | (M5)     | (M6)     | (M7)     | (M8)     | (M9)     |
| hiv                                        | -2.473*  | -2.469*  | -2.485   | -2.416    | -2.396   | -1.995   | -1.984   | -1.943   | -1.926   |
|                                            | (1.467)  | (1.469)  | (1.513)  | (1.490)   | (1.537)  | (1.261)  | (1.274)  | (1.265)  | (1.268)  |
| L.gold                                     | 0.627*** | 0.627*** | 0.627*** | 0.630***  | 0.634*** | 0.663*** | 0.665*** | 0.670*** | 0.671*** |
|                                            | (0.086)  | (0.086)  | (0.086)  | (0.086)   | (0.090)  | (0.086)  | (0.086)  | (0.087)  | (0.087)  |
| autocracy                                  | -0.727** | -0.726** | -0.727** | -0.754**  | -0.719** | -0.669** | -0.641** | -0.220   |          |
|                                            | (0.303)  | (0.303)  | (0.305)  | (0.306)   | (0.320)  | (0.277)  | (0.270)  | (0.142)  |          |
| democracy                                  | -0.495** | -0.494** | -0.494** | -0.506*** | -0.493** | -0.499** | -0.489** |          |          |
|                                            | (0.193)  | (0.194)  | (0.194)  | (0.196)   | (0.198)  | (0.202)  | (0.206)  |          |          |
| open                                       | -0.024   | -0.024   | -0.023   | -0.024    | -0.026   | -0.033   |          |          |          |
|                                            | (0.023)  | (0.023)  | (0.023)  | (0.023)   | (0.023)  | (0.021)  |          |          |          |
| unemployment                               | 1.039*   | 1.038*   | 1.047    | 1.043*    | 1.032    |          |          |          |          |
|                                            | (0.630)  | (0.623)  | (0.640)  | (0.634)   | (0.646)  |          |          |          |          |
| telinfrastructure                          | 0.736    | 0.721    | 0.721    | 0.700     |          |          |          |          |          |
|                                            | (0.456)  | (0.474)  | (0.478)  | (0.483)   |          |          |          |          |          |
| primary                                    | 0.038    | 0.037    | 0.037    |           |          |          |          |          |          |
|                                            | (0.051)  | (0.051)  | (0.052)  |           |          |          |          |          |          |
| gdpcap                                     | -0.000   | -0.000   |          |           |          |          |          |          |          |
|                                            | (0.001)  | (0.001)  |          |           |          |          |          |          |          |
| migcap                                     | -0.001   |          |          |           |          |          |          |          |          |
|                                            | (0.015)  |          |          |           |          |          |          |          |          |
| Time FE                                    | yes      | yes      | yes      | yes       | yes      | yes      | yes      | yes      | yes      |
| Country FE                                 | yes      | yes      | yes      | yes       | yes      | yes      | yes      | yes      | yes      |
| AR1 z-stat                                 | 0.032    | 0.032    | 0.033    | 0.033     | 0.031    | 0.043    | 0.043    | 0.043    | 0.043    |
| AR2 z-stat                                 | 0.139    | 0.142    | 0.142    | 0.148     | 0.149    | 0.196    | 0.185    | 0.185    | 0.186    |
| Hansen p-value                             | 1.000    | 1.000    | 1.000    | 1.000     | 1.000    | 0.000    | 1.000    | 1.000    | 1.000    |
| Instrument count                           | 152      | 151      | 150      | 149       | 148      | 147      | 146      | 145      | 144      |
| N                                          | 678      | 678      | 678      | 678       | 678      | 678      | 678      | 678      | 678      |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . The Arellano-Bond model is a GMM estimator with country clustered robust standard errors. This model assumes that lagged gold production is predetermined and HIV is endogenous. Consumption and countrysize have been eliminated as covariates.

## **7.2 Appendix B: PopART Statistics Excluding Triplet 2 (Chapters 3 & 4)**

*All tables on the following pages are referred to within the document.*

**Table 36***PopART Summary Statistics (Wave 1 – Total Sample)*

|                                                    | Mean  | SD    | Min  | Max | N      |
|----------------------------------------------------|-------|-------|------|-----|--------|
| Final HIV Status                                   | 0.218 | 0.413 | 0.0  | 1.0 | 30,202 |
| Healthcare Utilisation                             | 0.098 | 0.297 | 0.0  | 1.0 | 6,025  |
| Combined, Weighted Score (EQ5D)                    | 0.887 | 0.042 | -0.1 | 0.9 | 31,170 |
| Self-Care Today (Qolself)                          | 1.027 | 0.199 | 1.0  | 5.0 | 31,292 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.040 | 0.243 | 1.0  | 5.0 | 31,294 |
| Pain or Discomfort (Qolpain)                       | 1.113 | 0.390 | 1.0  | 5.0 | 31,294 |
| Anxiety or Depression (Qolanx)                     | 1.097 | 0.381 | 1.0  | 5.0 | 31,282 |
| Mobility (Qolmob)                                  | 1.031 | 0.222 | 1.0  | 5.0 | 31,192 |
| Employment Status (Working)                        | 0.255 | 0.436 | 0.0  | 1.0 | 31,316 |
| Male/Female(Sex)                                   | 0.302 | 0.459 | 0.0  | 1.0 | 31,325 |
| Wealth                                             | 0.100 | 1.681 | -5.9 | 3.8 | 31,325 |
| Baseline Wealth                                    | 0.100 | 1.681 | -5.9 | 3.8 | 31,325 |
| Education Status (Education)                       | 1.920 | 0.476 | 0.0  | 3.0 | 31,325 |
| Working Formally (Workformal)                      | 0.496 | 0.500 | 0.0  | 1.0 | 7,916  |

**Table 37***PopART Summary Statistics (Wave 2 – Total Sample)*

|                                                    | Mean  | SD    | Min  | Max | N      |
|----------------------------------------------------|-------|-------|------|-----|--------|
| Final HIV Status                                   | 0.232 | 0.422 | 0.0  | 1.0 | 23,073 |
| Healthcare Utilisation                             | 0.127 | 0.333 | 0.0  | 1.0 | 4,778  |
| Combined, Weighted Score (EQ5D)                    | 0.889 | 0.038 | 0.1  | 0.9 | 24,729 |
| Self-Care Today (Qolself)                          | 1.021 | 0.192 | 1.0  | 5.0 | 24,804 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.035 | 0.237 | 1.0  | 5.0 | 24,792 |
| Pain or Discomfort (Qolpain)                       | 1.105 | 0.390 | 1.0  | 5.0 | 24,794 |
| Anxiety or Depression (Qolanx)                     | 1.060 | 0.325 | 1.0  | 5.0 | 24,770 |
| Mobility (Qolmob)                                  | 1.029 | 0.222 | 1.0  | 5.0 | 24,812 |
| Employment Status (Working)                        | 0.369 | 0.483 | 0.0  | 1.0 | 24,855 |
| Male/Female(Sex)                                   | 0.286 | 0.452 | 0.0  | 1.0 | 24,926 |
| Wealth                                             | 0.188 | 1.581 | -5.9 | 3.7 | 24,926 |
| Baseline Wealth                                    | 0.214 | 1.624 | -5.9 | 3.7 | 20,133 |
| Education Status (Education)                       | 1.921 | 0.483 | 0.0  | 3.0 | 24,926 |
| Working Formally (Workformal)                      | 0.508 | 0.500 | 0.0  | 1.0 | 9,149  |

**Table 38***PopART Summary Statistics (Wave 3 – Total Sample)*

|                                                    | Mean  | SD    | Min  | Max | N      |
|----------------------------------------------------|-------|-------|------|-----|--------|
| Final HIV Status                                   | 0.238 | 0.426 | 0.0  | 1.0 | 23,069 |
| Healthcare Utilisation                             | 0.079 | 0.270 | 0.0  | 1.0 | 4,845  |
| Combined, Weighted Score (EQ5D)                    | 0.889 | 0.038 | -0.1 | 0.9 | 24,433 |
| Self-Care Today (Qolself)                          | 1.020 | 0.176 | 1.0  | 5.0 | 24,453 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.034 | 0.217 | 1.0  | 5.0 | 24,451 |
| Pain or Discomfort (Qolpain)                       | 1.106 | 0.388 | 1.0  | 5.0 | 24,447 |
| Anxiety or Depression (Qolanx)                     | 1.065 | 0.323 | 1.0  | 5.0 | 24,441 |
| Mobility (Qolmob)                                  | 1.029 | 0.220 | 1.0  | 5.0 | 24,451 |
| Employment Status (Working)                        | 0.430 | 0.495 | 0.0  | 1.0 | 24,471 |
| Male/Female (Sex)                                  | 0.280 | 0.449 | 0.0  | 1.0 | 24,488 |
| Wealth                                             | 0.194 | 1.591 | -5.9 | 3.8 | 24,488 |
| Baseline Wealth                                    | 0.236 | 1.621 | -5.9 | 3.7 | 17,552 |
| Education Status (Education)                       | 1.913 | 0.489 | 0.0  | 3.0 | 24,488 |
| Working Formally (Workformal)                      | 0.529 | 0.499 | 0.0  | 1.0 | 10,504 |

**Table 39***PopART Summary Statistics (Wave 4 – Total Sample)*

|                                                    | Mean  | SD    | Min  | Max | N      |
|----------------------------------------------------|-------|-------|------|-----|--------|
| Final HIV Status                                   | 0.242 | 0.428 | 0.0  | 1.0 | 21,631 |
| Healthcare Utilisation                             | 0.069 | 0.254 | 0.0  | 1.0 | 4,203  |
| Combined, Weighted Score (EQ5D)                    | 0.892 | 0.032 | 0.3  | 0.9 | 22,073 |
| Self-Care Today (Qolself)                          | 1.016 | 0.154 | 1.0  | 5.0 | 22,092 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.025 | 0.192 | 1.0  | 5.0 | 22,090 |
| Pain or Discomfort (Qolpain)                       | 1.080 | 0.347 | 1.0  | 5.0 | 22,088 |
| Anxiety or Depression (Qolanx)                     | 1.056 | 0.321 | 1.0  | 5.0 | 22,092 |
| Mobility (Qolmob)                                  | 1.019 | 0.180 | 1.0  | 5.0 | 22,088 |
| Employment Status (Working)                        | 0.467 | 0.499 | 0.0  | 1.0 | 22,091 |
| Male/Female (Sex)                                  | 0.275 | 0.447 | 0.0  | 1.0 | 22,102 |
| Wealth                                             | 0.278 | 1.519 | -5.9 | 3.7 | 22,102 |
| Baseline Wealth                                    | 0.253 | 1.615 | -5.9 | 3.7 | 16,229 |
| Education Status (Education)                       | 1.913 | 0.489 | 0.0  | 3.0 | 22,102 |
| Working Formally (Workformal)                      | 0.548 | 0.498 | 0.0  | 1.0 | 10,309 |

**Table 40***PopART Summary Statistics Excluding Triplet 2 (Avg. Waves 2–4 – Total)*

|                                                    | Mean  | SD    | Min  | Max | N      |
|----------------------------------------------------|-------|-------|------|-----|--------|
| Final HIV Status                                   | 0.243 | 0.429 | 0.0  | 1.0 | 29,649 |
| Healthcare Utilisation                             | 0.087 | 0.282 | 0.0  | 1.0 | 11,857 |
| Combined, Weighted Score (EQ5D)                    | 0.890 | 0.029 | 0.3  | 0.9 | 30,839 |
| Self-Care Today (Qolself)                          | 1.019 | 0.137 | 1.0  | 5.0 | 30,855 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.032 | 0.166 | 1.0  | 5.0 | 30,848 |
| Pain or Discomfort (Qolpain)                       | 1.096 | 0.282 | 1.0  | 5.0 | 30,852 |
| Anxiety or Depression (Qolanx)                     | 1.060 | 0.255 | 1.0  | 5.0 | 30,853 |
| Mobility (Qolmob)                                  | 1.027 | 0.165 | 1.0  | 5.0 | 30,858 |
| Employment Status (Working)                        | 0.413 | 0.418 | 0.0  | 1.0 | 30,873 |
| Male/Female(Sex)                                   | 0.289 | 0.453 | 0.0  | 1.0 | 30,917 |
| Wealth                                             | 0.164 | 1.453 | -5.9 | 3.7 | 30,917 |
| Baseline Wealth                                    | 0.205 | 1.637 | -5.9 | 3.7 | 22,545 |
| Education Status (Education)                       | 1.918 | 0.488 | 0.0  | 3.0 | 30,917 |
| Working Formally (Workformal)                      | 0.493 | 0.457 | 0.0  | 1.0 | 17,390 |

**Table 41***PopART Summary Statistics (Wave 1 – Treated)*

|                                                    | Mean   | SD    | Min  | Max | N      |
|----------------------------------------------------|--------|-------|------|-----|--------|
| Final HIV Status                                   | 0.215  | 0.411 | 0.0  | 1.0 | 22,443 |
| Healthcare Utilisation                             | 0.076  | 0.265 | 0.0  | 1.0 | 4,354  |
| Combined, Weighted Score (EQ5D)                    | 0.889  | 0.038 | -0.1 | 0.9 | 23,133 |
| Self-Care Today (Qolself)                          | 1.022  | 0.177 | 1.0  | 5.0 | 23,231 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.032  | 0.212 | 1.0  | 5.0 | 23,232 |
| Pain or Discomfort (Qolpain)                       | 1.099  | 0.373 | 1.0  | 5.0 | 23,232 |
| Anxiety or Depression (Qolanx)                     | 1.085  | 0.359 | 1.0  | 5.0 | 23,221 |
| Mobility (Qolmob)                                  | 1.024  | 0.204 | 1.0  | 5.0 | 23,153 |
| Employment Status (Working)                        | 0.272  | 0.445 | 0.0  | 1.0 | 23,247 |
| Male/Female (Sex)                                  | 0.287  | 0.452 | 0.0  | 1.0 | 23,253 |
| Wealth                                             | -0.525 | 1.878 | -5.9 | 3.7 | 23,253 |
| Baseline Wealth                                    | -0.525 | 1.878 | -5.9 | 3.7 | 23,253 |
| Education Status (Education)                       | 1.834  | 0.518 | 0.0  | 3.0 | 23,253 |
| Working Formally (Workformal)                      | 0.390  | 0.488 | 0.0  | 1.0 | 6,273  |

**Table 42***PopART Summary Statistics (Wave 2 – Treated)*

|                                                    | Mean   | SD    | Min  | Max | N      |
|----------------------------------------------------|--------|-------|------|-----|--------|
| Final HIV Status                                   | 0.229  | 0.420 | 0.0  | 1.0 | 15,778 |
| Healthcare Utilisation                             | 0.126  | 0.332 | 0.0  | 1.0 | 3,292  |
| Combined, Weighted Score (EQ5D)                    | 0.891  | 0.038 | -0.0 | 0.9 | 16,731 |
| Self-Care Today (Qolself)                          | 1.024  | 0.208 | 1.0  | 5.0 | 16,798 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.037  | 0.252 | 1.0  | 5.0 | 16,785 |
| Pain or Discomfort (Qolpain)                       | 1.081  | 0.337 | 1.0  | 5.0 | 16,786 |
| Anxiety or Depression (Qolanx)                     | 1.053  | 0.302 | 1.0  | 5.0 | 16,764 |
| Mobility (Qolmob)                                  | 1.027  | 0.209 | 1.0  | 5.0 | 16,804 |
| Employment Status (Working)                        | 0.378  | 0.485 | 0.0  | 1.0 | 16,841 |
| Male/Female (Sex)                                  | 0.265  | 0.441 | 0.0  | 1.0 | 16,897 |
| Wealth                                             | -0.384 | 1.729 | -5.9 | 3.7 | 16,897 |
| Baseline Wealth                                    | -0.384 | 1.845 | -5.9 | 3.7 | 14,528 |
| Education Status (Education)                       | 1.834  | 0.517 | 0.0  | 3.0 | 16,897 |
| Working Formally (Workformal)                      | 0.435  | 0.496 | 0.0  | 1.0 | 6,348  |

**Table 43***PopART Summary Statistics (Wave 3 – Treated)*

|                                                    | Mean   | SD    | Min  | Max | N      |
|----------------------------------------------------|--------|-------|------|-----|--------|
| Final HIV Status                                   | 0.233  | 0.423 | 0.0  | 1.0 | 16,103 |
| Healthcare Utilisation                             | 0.057  | 0.232 | 0.0  | 1.0 | 3,457  |
| Combined, Weighted Score (EQ5D)                    | 0.889  | 0.039 | -0.1 | 0.9 | 17,055 |
| Self-Care Today (Qolself)                          | 1.021  | 0.182 | 1.0  | 5.0 | 17,073 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.037  | 0.227 | 1.0  | 5.0 | 17,072 |
| Pain or Discomfort (Qolpain)                       | 1.093  | 0.358 | 1.0  | 5.0 | 17,067 |
| Anxiety or Depression (Qolanx)                     | 1.064  | 0.315 | 1.0  | 5.0 | 17,062 |
| Mobility (Qolmob)                                  | 1.030  | 0.230 | 1.0  | 5.0 | 17,071 |
| Employment Status (Working)                        | 0.423  | 0.494 | 0.0  | 1.0 | 17,079 |
| Male/Female (Sex)                                  | 0.260  | 0.439 | 0.0  | 1.0 | 17,095 |
| Wealth                                             | -0.322 | 1.693 | -5.9 | 3.8 | 17,095 |
| Baseline Wealth                                    | -0.353 | 1.849 | -5.9 | 3.7 | 13,053 |
| Education Status (Education)                       | 1.829  | 0.522 | 0.0  | 3.0 | 17,095 |
| Working Formally (Workformal)                      | 0.490  | 0.500 | 0.0  | 1.0 | 7,210  |

**Table 44***PopART Summary Statistics (Wave 4 – Treated)*

|                                                    | Mean   | SD    | Min  | Max | N      |
|----------------------------------------------------|--------|-------|------|-----|--------|
| Final HIV Status                                   | 0.236  | 0.425 | 0.0  | 1.0 | 15,433 |
| Healthcare Utilisation                             | 0.069  | 0.254 | 0.0  | 1.0 | 3,010  |
| Combined, Weighted Score (EQ5D)                    | 0.892  | 0.032 | 0.3  | 0.9 | 15,745 |
| Self-Care Today (Qolself)                          | 1.018  | 0.160 | 1.0  | 5.0 | 15,758 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.028  | 0.191 | 1.0  | 5.0 | 15,755 |
| Pain or Discomfort (Qolpain)                       | 1.072  | 0.315 | 1.0  | 5.0 | 15,752 |
| Anxiety or Depression (Qolanx)                     | 1.056  | 0.308 | 1.0  | 5.0 | 15,754 |
| Mobility (Qolmob)                                  | 1.020  | 0.178 | 1.0  | 5.0 | 15,754 |
| Employment Status (Working)                        | 0.466  | 0.499 | 0.0  | 1.0 | 15,753 |
| Male/Female (Sex)                                  | 0.253  | 0.435 | 0.0  | 1.0 | 15,763 |
| Wealth                                             | -0.267 | 1.672 | -5.9 | 3.7 | 15,763 |
| Baseline Wealth                                    | -0.399 | 1.859 | -5.9 | 3.7 | 12,336 |
| Education Status (Education)                       | 1.820  | 0.525 | 0.0  | 3.0 | 15,763 |
| Working Formally (Workformal)                      | 0.492  | 0.500 | 0.0  | 1.0 | 7,327  |

**Table 45***PopART Summary Statistics (Avg. Waves 2–4 – Treated)*

|                                                    | Mean   | SD    | Min  | Max | N      |
|----------------------------------------------------|--------|-------|------|-----|--------|
| Final HIV Status                                   | 0.237  | 0.425 | 0.0  | 1.0 | 20,521 |
| Healthcare Utilisation                             | 0.070  | 0.255 | 0.0  | 1.0 | 8,386  |
| Combined, Weighted Score (EQ5D)                    | 0.891  | 0.029 | -0.0 | 0.9 | 21,208 |
| Self-Care Today (Qolself)                          | 1.021  | 0.145 | 1.0  | 5.0 | 21,220 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.034  | 0.169 | 1.0  | 5.0 | 21,216 |
| Pain or Discomfort (Qolpain)                       | 1.081  | 0.252 | 1.0  | 5.0 | 21,219 |
| Anxiety or Depression (Qolanx)                     | 1.057  | 0.240 | 1.0  | 5.0 | 21,219 |
| Mobility (Qolmob)                                  | 1.027  | 0.162 | 1.0  | 5.0 | 21,223 |
| Employment Status (Working)                        | 0.415  | 0.416 | 0.0  | 1.0 | 21,230 |
| Male/Female(Sex)                                   | 0.269  | 0.444 | 0.0  | 1.0 | 21,266 |
| Wealth                                             | -0.384 | 1.581 | -5.9 | 3.7 | 21,266 |
| Baseline Wealth                                    | -0.414 | 1.863 | -5.9 | 3.7 | 16,456 |
| Education Status (Education)                       | 1.830  | 0.523 | 0.0  | 3.0 | 21,266 |
| Working Formally (Workformal)                      | 0.441  | 0.454 | 0.0  | 1.0 | 12,116 |

**Table 46***PopART Summary Statistics (Wave 1 – Control)*

|                                                    | Mean  | SD    | Min  | Max | N      |
|----------------------------------------------------|-------|-------|------|-----|--------|
| Final HIV Status                                   | 0.230 | 0.421 | 0.0  | 1.0 | 10,057 |
| Healthcare Utilisation                             | 0.103 | 0.304 | 0.0  | 1.0 | 2,169  |
| Combined, Weighted Score (EQ5D)                    | 0.885 | 0.048 | -0.0 | 0.9 | 10,368 |
| Self-Care Today (Qolself)                          | 1.035 | 0.234 | 1.0  | 5.0 | 10,394 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.051 | 0.275 | 1.0  | 5.0 | 10,395 |
| Pain or Discomfort (Qolpain)                       | 1.139 | 0.432 | 1.0  | 5.0 | 10,395 |
| Anxiety or Depression (Qolanx)                     | 1.095 | 0.385 | 1.0  | 5.0 | 10,394 |
| Mobility (Qolmob)                                  | 1.040 | 0.255 | 1.0  | 5.0 | 10,369 |
| Employment Status (Working)                        | 0.237 | 0.425 | 0.0  | 1.0 | 10,399 |
| Male/Female (Sex)                                  | 0.309 | 0.462 | 0.0  | 1.0 | 10,403 |
| Wealth                                             | 0.317 | 1.477 | -5.9 | 3.8 | 10,403 |
| Baseline Wealth                                    | 0.317 | 1.477 | -5.9 | 3.8 | 10,403 |
| Education Status (Education)                       | 1.901 | 0.484 | 0.0  | 3.0 | 10,403 |
| Working Formally (Workformal)                      | 0.523 | 0.500 | 0.0  | 1.0 | 2,461  |

**Table 47** *PopART Summary Statistics (Wave 2 – Control)*

|                                                    | Mean  | SD    | Min  | Max | N     |
|----------------------------------------------------|-------|-------|------|-----|-------|
| Final HIV Status                                   | 0.255 | 0.436 | 0.0  | 1.0 | 7,208 |
| Healthcare Utilisation                             | 0.077 | 0.266 | 0.0  | 1.0 | 1,514 |
| Combined, Weighted Score (EQ5D)                    | 0.890 | 0.035 | 0.1  | 0.9 | 7,910 |
| Self-Care Today (Qolself)                          | 1.016 | 0.161 | 1.0  | 4.0 | 7,916 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.029 | 0.213 | 1.0  | 5.0 | 7,916 |
| Pain or Discomfort (Qolpain)                       | 1.107 | 0.392 | 1.0  | 5.0 | 7,917 |
| Anxiety or Depression (Qolanx)                     | 1.053 | 0.293 | 1.0  | 5.0 | 7,917 |
| Mobility (Qolmob)                                  | 1.023 | 0.195 | 1.0  | 5.0 | 7,916 |
| Employment Status (Working)                        | 0.356 | 0.479 | 0.0  | 1.0 | 7,935 |
| Male/Female (Sex)                                  | 0.300 | 0.458 | 0.0  | 1.0 | 7,946 |
| Wealth                                             | 0.264 | 1.421 | -5.0 | 3.7 | 7,946 |
| Baseline Wealth                                    | 0.372 | 1.423 | -5.9 | 3.7 | 6,947 |
| Education Status (Education)                       | 1.896 | 0.483 | 0.0  | 3.0 | 7,946 |
| Working Formally (Workformal)                      | 0.547 | 0.498 | 0.0  | 1.0 | 2,820 |

**Table 48***PopART Summary Statistics (Wave 3 – Control)*

|                                                    | Mean  | SD    | Min  | Max | N     |
|----------------------------------------------------|-------|-------|------|-----|-------|
| Final HIV Status                                   | 0.258 | 0.438 | 0.0  | 1.0 | 7,747 |
| Healthcare Utilisation                             | 0.078 | 0.269 | 0.0  | 1.0 | 1,559 |
| Combined, Weighted Score (EQ5D)                    | 0.890 | 0.036 | -0.1 | 0.9 | 8,230 |
| Self-Care Today (Qolself)                          | 1.019 | 0.165 | 1.0  | 5.0 | 8,232 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.029 | 0.196 | 1.0  | 5.0 | 8,231 |
| Pain or Discomfort (Qolpain)                       | 1.102 | 0.379 | 1.0  | 5.0 | 8,232 |
| Anxiety or Depression (Qolanx)                     | 1.043 | 0.249 | 1.0  | 5.0 | 8,231 |
| Mobility (Qolmob)                                  | 1.023 | 0.182 | 1.0  | 5.0 | 8,232 |
| Employment Status (Working)                        | 0.402 | 0.490 | 0.0  | 1.0 | 8,243 |
| Male/Female (Sex)                                  | 0.292 | 0.455 | 0.0  | 1.0 | 8,245 |
| Wealth                                             | 0.232 | 1.554 | -5.9 | 3.8 | 8,245 |
| Baseline Wealth                                    | 0.378 | 1.428 | -5.9 | 3.7 | 5,757 |
| Education Status (Education)                       | 1.885 | 0.495 | 0.0  | 3.0 | 8,245 |
| Working Formally (Workformal)                      | 0.518 | 0.500 | 0.0  | 1.0 | 3,312 |

**Table 49***PopART Summary Statistics (Wave 4 – Control)*

|                                                    | Mean  | SD    | Min  | Max | N     |
|----------------------------------------------------|-------|-------|------|-----|-------|
| Final HIV Status                                   | 0.260 | 0.439 | 0.0  | 1.0 | 7,080 |
| Healthcare Utilisation                             | 0.046 | 0.210 | 0.0  | 1.0 | 1,381 |
| Combined, Weighted Score (EQ5D)                    | 0.893 | 0.029 | 0.4  | 0.9 | 7,205 |
| Self-Care Today (Qolself)                          | 1.012 | 0.132 | 1.0  | 5.0 | 7,210 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.021 | 0.190 | 1.0  | 5.0 | 7,210 |
| Pain or Discomfort (Qolpain)                       | 1.080 | 0.354 | 1.0  | 5.0 | 7,212 |
| Anxiety or Depression (Qolanx)                     | 1.025 | 0.193 | 1.0  | 4.0 | 7,212 |
| Mobility (Qolmob)                                  | 1.016 | 0.179 | 1.0  | 5.0 | 7,210 |
| Employment Status (Working)                        | 0.451 | 0.498 | 0.0  | 1.0 | 7,212 |
| Male/Female (Sex)                                  | 0.288 | 0.453 | 0.0  | 1.0 | 7,213 |
| Wealth                                             | 0.313 | 1.410 | -5.2 | 3.7 | 7,213 |
| Baseline Wealth                                    | 0.405 | 1.423 | -5.9 | 3.7 | 5,238 |
| Education Status (Education)                       | 1.885 | 0.499 | 0.0  | 3.0 | 7,213 |
| Working Formally (Workformal)                      | 0.540 | 0.499 | 0.0  | 1.0 | 3,251 |

**Table 50***PopART Summary Statistics (Avg. Waves 2–4 – Control)*

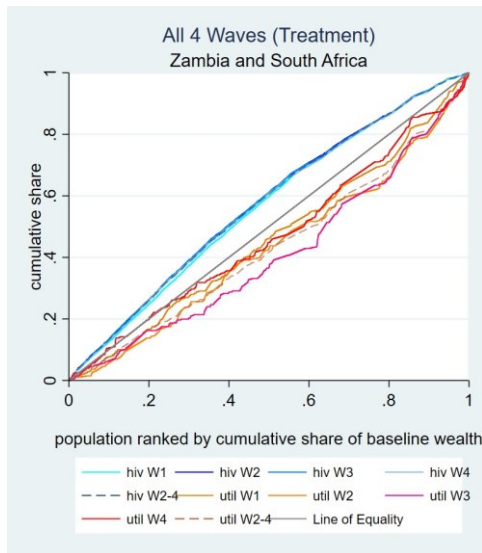
|                                                    | Mean  | SD    | Min  | Max | N      |
|----------------------------------------------------|-------|-------|------|-----|--------|
| Final HIV Status                                   | 0.262 | 0.440 | 0.0  | 1.0 | 9,990  |
| Healthcare Utilisation                             | 0.078 | 0.268 | 0.0  | 1.0 | 3,855  |
| Combined, Weighted Score (EQ5D)                    | 0.891 | 0.027 | 0.3  | 0.9 | 10,472 |
| Self-Care Today (Qolself)                          | 1.016 | 0.121 | 1.0  | 5.0 | 10,474 |
| Usual Activities – Work, Study, Housework (Qolact) | 1.027 | 0.155 | 1.0  | 5.0 | 10,472 |
| Pain or Discomfort (Qolpain)                       | 1.098 | 0.292 | 1.0  | 5.0 | 10,473 |
| Anxiety or Depression (Qolanx)                     | 1.044 | 0.215 | 1.0  | 5.0 | 10,474 |
| Mobility (Qolmob)                                  | 1.021 | 0.146 | 1.0  | 5.0 | 10,474 |
| Employment Status (Working)                        | 0.392 | 0.418 | 0.0  | 1.0 | 10,484 |
| Male/Female(Sex)                                   | 0.299 | 0.458 | 0.0  | 1.0 | 10,490 |
| Wealth                                             | 0.236 | 1.348 | -5.1 | 3.7 | 10,490 |
| Baseline Wealth                                    | 0.376 | 1.436 | -5.9 | 3.7 | 7,715  |
| Education Status (Education)                       | 1.894 | 0.490 | 0.0  | 3.0 | 10,490 |
| Working Formally (Workformal)                      | 0.501 | 0.461 | 0.0  | 1.0 | 5,587  |

### **7.3 Appendix C: Additional Data, Methods, and Results for Chapter 3**

*All tables on the following pages are referred to within the document.*

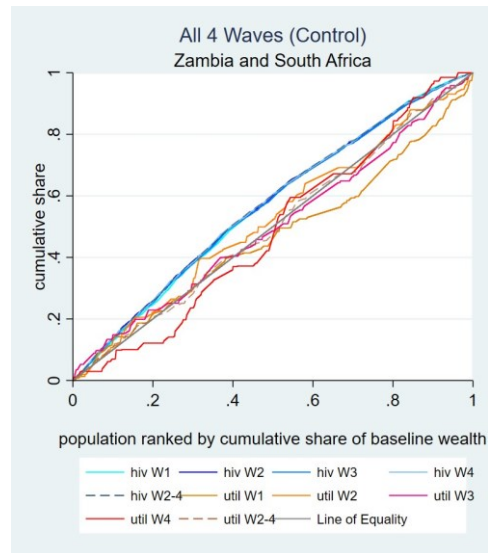
**Figure 32**

*Concentration Curves – Treated Ranked by Baseline Wealth*



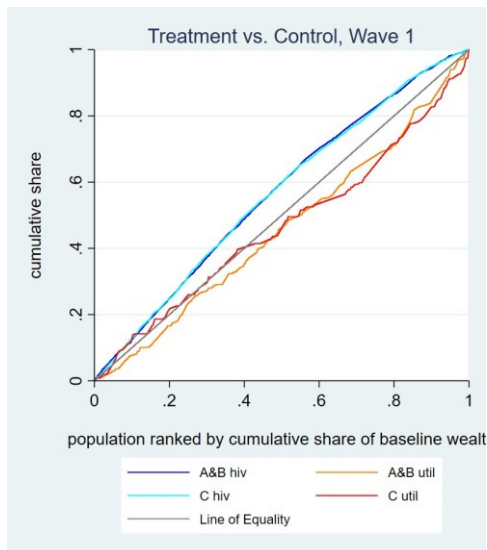
**Figure 33**

*Concentration Curves – Control Ranked by Baseline Wealth*



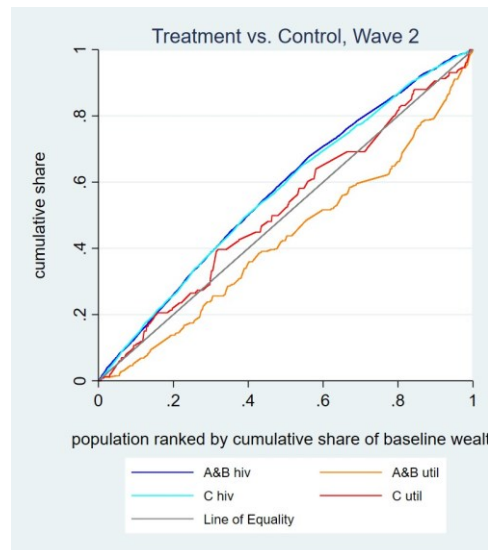
**Figure 34**

*Concentration Curves – Wave 1 Ranked by Baseline Wealth*



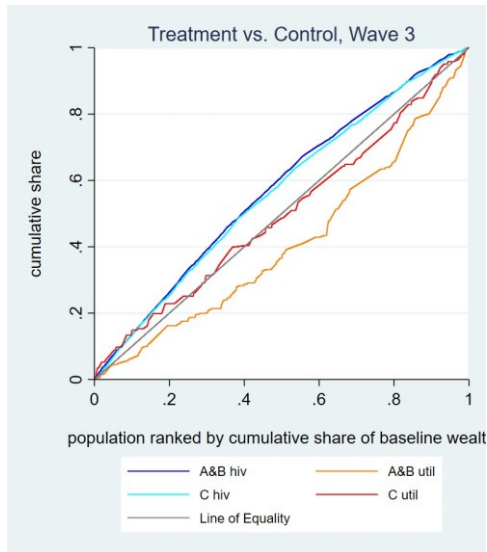
**Figure 35**

*Concentration Curves – Wave 2 Ranked by Baseline Wealth*



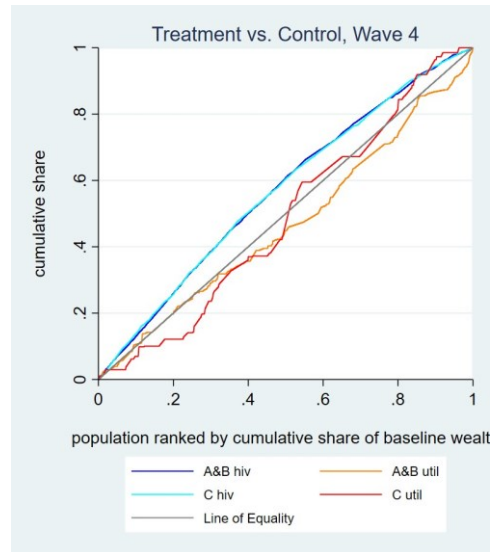
**Figure 36**

*Concentration Curves – Wave 3 Ranked by Baseline Wealth*



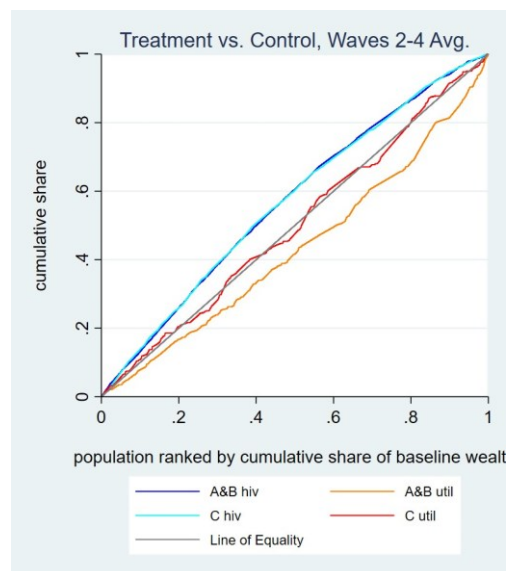
**Figure 37**

*Concentration Curves – Wave 4 Ranked by Baseline Wealth*



**Figure 38**

*Concentration Curves – Avg. Ranked by Baseline Wealth*



**Table 51**

*HIV Prevalence Index by Wave – Treated Ranked by  
Baseline Wealth*

|                     | (W1)      | (W2)      | (W3)      | (W4)      | (W2–4)    |
|---------------------|-----------|-----------|-----------|-----------|-----------|
| <b>Zambia</b>       |           |           |           |           |           |
| <b>Triplet 1</b>    | -0.095*** | -0.124*** | -0.107*** | -0.106*** | -0.103*** |
| Community 1         | (0.026)   | (0.032)   | (0.035)   | (0.035)   | (0.031)   |
|                     | [972]     | [677]     | [609]     | [636]     | [768]     |
| Community 2         | -0.074*** | -0.101*** | -0.100*** | -0.108*** | -0.100*** |
|                     | (0.025)   | (0.032)   | (0.033)   | (0.034)   | (0.031)   |
|                     | [1,002]   | [658]     | [620]     | [625]     | [1,297]   |
| <b>Triplet 3</b>    | -0.061*** | -0.113*** | -0.085**  | -0.083**  | -0.103*** |
| Community 8         | (0.020)   | (0.033)   | (0.035)   | (0.037)   | (0.030)   |
|                     | [1,570]   | [771]     | [709]     | [701]     | [934]     |
| Community 9         | -0.091*** | -0.103*** | -0.071*   | -0.077**  | -0.088*** |
|                     | (0.024)   | (0.037)   | (0.038)   | (0.039)   | (0.033)   |
|                     | [1,372]   | [720]     | [686]     | [688]     | [893]     |
| <b>Triplet 4</b>    | -0.073*** | -0.093*** | -0.105*** | -0.108*** | -0.104*** |
| Community 10        | (0.020)   | (0.031)   | (0.033)   | (0.033)   | (0.030)   |
|                     | [1,741]   | [1,110]   | [994]     | [980]     | [1,192]   |
| Community 11        | -0.064*** | -0.105*** | -0.104*** | -0.141*** | -0.109*** |
|                     | (0.024)   | (0.038)   | (0.036)   | (0.037)   | (0.033)   |
|                     | [1,345]   | [948]     | [767]     | [730]     | [897]     |
| <b>South Africa</b> |           |           |           |           |           |
| <b>Triplet 5</b>    | -0.072*** | -0.079*** | -0.053*   | -0.057*   | -0.067*** |
| Community 13        | (0.022)   | (0.028)   | (0.030)   | (0.031)   | (0.026)   |
|                     | [2,287]   | [1,392]   | [1,191]   | [1,134]   | [1,641]   |
| Community 14        | -0.092*** | -0.091*** | -0.094*** | -0.077**  | -0.080*** |
|                     | (0.023)   | (0.028)   | (0.030)   | (0.032)   | (0.026)   |
|                     | [2,084]   | [1,195]   | [979]     | [921]     | [1,379]   |
| <b>Triplet 6</b>    | -0.092*** | -0.105*** | -0.099*** | -0.112*** | -0.109*** |
| Community 16        | (0.023)   | (0.027)   | (0.031)   | (0.031)   | (0.026)   |
|                     | [1,986]   | [1,449]   | [998]     | [1,033]   | [1,429]   |
| Community 18        | -0.107*** | -0.103*** | -0.122*** | -0.096*** | -0.107*** |
|                     | (0.019)   | (0.025)   | (0.026)   | (0.026)   | (0.024)   |
|                     | [2,264]   | [1,178]   | [1,049]   | [1,104]   | [1,391]   |
| <b>Triplet 7</b>    | -0.136*** | -0.129*** | -0.114*** | -0.094*** | -0.129*** |
| Community 19        | (0.016)   | (0.018)   | (0.020)   | (0.021)   | (0.018)   |
|                     | [1,654]   | [1,180]   | [1,035]   | [970]     | [1,312]   |
| Community 20        | -0.142*** | -0.091*** | -0.082*** | -0.080*** | -0.091*** |
|                     | (0.014)   | (0.016)   | (0.017)   | (0.018)   | (0.016)   |
|                     | [1,943]   | [1,465]   | [1,303]   | [1,237]   | [1,569]   |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses. Observation count in brackets.

**Table 52**

*HIV Prevalence Index by Wave – Control Ranked by  
Baseline Wealth*

|                     | (W1)      | (W2)      | (W3)      | (W4)      | (W2–4)    |
|---------------------|-----------|-----------|-----------|-----------|-----------|
| <b>Zambia</b>       |           |           |           |           |           |
| <b>Triplet 1</b>    | -0.063*** | -0.046*   | -0.059**  | -0.075**  | -0.068**  |
| Community 3         | (0.022)   | (0.027)   | (0.030)   | (0.030)   | (0.026)   |
|                     | [1,761]   | [1,203]   | [1,040]   | [1,057]   | [1,323]   |
| <b>Triplet 3</b>    | -0.069*** | -0.138*** | -0.148*** | -0.135*** | -0.131*** |
| Community 7         | (0.018)   | (0.030)   | (0.032)   | (0.031)   | (0.026)   |
|                     | [2,090]   | [933]     | [861]     | [918]     | [1,336]   |
| <b>Triplet 4</b>    | -0.119*** | -0.168*** | -0.160*** | -0.187*** | -0.190*** |
| Community 12        | (0.032)   | (0.038)   | (0.042)   | (0.042)   | (0.037)   |
|                     | [1,032]   | [753]     | [639]     | [649]     | [810]     |
| <b>South Africa</b> |           |           |           |           |           |
| <b>Triplet 5</b>    | -0.128*** | -0.167*** | -0.140*** | -0.171*** | -0.145*** |
| Community 15        | (0.023)   | (0.031)   | (0.037)   | (0.039)   | (0.030)   |
|                     | [1,826]   | [1,072]   | [819]     | [754]     | [1,243]   |
| <b>Triplet 6</b>    | -0.039*   | -0.020    | -0.057    | -0.032    | -0.038    |
| Community 17        | (0.023)   | (0.032)   | (0.037)   | (0.039)   | (0.030)   |
|                     | [1,928]   | [1,156]   | [890]     | [1,189]   | [1,307]   |
| <b>Triplet 7</b>    | -0.026*** | -0.025**  | -0.022*   | -0.032**  | -0.030**  |
| Community 21        | (0.010)   | (0.012)   | (0.013)   | (0.014)   | (0.013)   |
|                     | [1,473]   | [1,129]   | [1,041]   | [962]     | [1,230]   |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses. Observation count in brackets.

**Table 53**

*Healthcare Utilisation Index by Wave – Treated Ranked by  
Baseline Wealth*

|                     | (W1)     | (W2)    | (W3)    | (W4)    | (W2-4)  |
|---------------------|----------|---------|---------|---------|---------|
| <b>Zambia</b>       |          |         |         |         |         |
| <b>Triplet 1</b>    | 0.094    | -0.026  | 0.054   | 0.081   | 0.072   |
| Community 1         | (0.070)  | (0.077) | (0.095) | (0.089) | (0.054) |
|                     | [193]    | [143]   | [123]   | [107]   | [329]   |
| Community 2         | -0.053   | 0.104   | 0.015   | -0.039  | 0.040   |
|                     | (0.052)  | (0.066) | (0.066) | (0.060) | (0.044) |
|                     | [216]    | [124]   | [115]   | [107]   | [291]   |
| <b>Triplet 3</b>    | 0.092    | -0.085  | -0.032  | -0.028  | -0.048  |
| Community 8         | (0.087)  | (0.060) | (0.087) | (0.065) | (0.043) |
|                     | [280]    | [147]   | [130]   | [135]   | [371]   |
| Community 9         | 0.074    | 0.047   | -0.085  | 0.064   | 0.002   |
|                     | (0.070)  | (0.063) | (0.053) | (0.055) | (0.038) |
|                     | [269]    | [125]   | [134]   | [114]   | [319]   |
| <b>Triplet 4</b>    | 0.297*** | 0.008   | 0.046   | -0.065  | 0.005   |
| Community 10        | (0.073)  | (0.038) | (0.040) | (0.046) | (0.027) |
|                     | [337]    | [207]   | [210]   | [177]   | [510]   |
| Community 11        | 0.222    | 0.042   | -0.023  | 0.017   | 0.013   |
|                     | (0.137)  | (0.037) | (0.030) | (0.016) | (0.020) |
|                     | [215]    | [132]   | [176]   | [147]   | [388]   |
| <b>South Africa</b> |          |         |         |         |         |
| <b>Triplet 5</b>    | 0.457**  | 0.050   | 0.042   | 0.055*  | 0.056** |
| Community 13        | (0.091)  | (0.043) | (0.037) | (0.031) | (0.024) |
|                     | [428]    | [267]   | [250]   | [240]   | [689]   |
| Community 14        | 0.250    | -0.011  | -0.008  | 0.015   | -0.004  |
|                     | (0.094)  | (0.017) | (0.010) | (0.024) | (0.011) |
|                     | [335]    | [236]   | [209]   | [171]   | [539]   |
| <b>Triplet 6</b>    | 0.212    | 0.000   | 0.003   | -0.022  | -0.008  |
| Community 16        | (0.338)  | (0.000) | (0.024) | (0.015) | (0.010) |
|                     | [372]    | [223]   | [192]   | [211]   | [548]   |
| Community 18        | 0.355*** | -0.050* | -0.009  | -0.030  | -0.025  |
|                     | (0.131)  | (0.027) | (0.023) | (0.051) | (0.023) |
|                     | [414]    | [221]   | [212]   | [564]   | [564]   |
| <b>Triplet 7</b>    | 0.266**  | 0.033   | -0.010  | 0.002   | 0.011   |
| Community 19        | (0.119)  | (0.029) | (0.040) | (0.038) | (0.023) |
|                     | [345]    | [234]   | [214]   | [190]   | [553]   |
| Community 20        | 0.097    | 0.014   | -0.029  | -0.006  | -0.014  |
|                     | (0.173)  | (0.023) | (0.035) | (0.024) | (0.019) |
|                     | [338]    | [280]   | [260]   | [193]   | [642]   |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses. Observation count in brackets.

**Table 54**  
*Healthcare Utilisation Index by Wave – Control Ranked by  
Baseline Wealth*

|                     | (W1)    | (W2)      | (W3)    | (W4)    | (W2–4)    |
|---------------------|---------|-----------|---------|---------|-----------|
| <b>Zambia</b>       |         |           |         |         |           |
| <b>Triplet 1</b>    | 0.097** | -0.012    | -0.020  | 0.000   | -0.008    |
| Community 3         | (0.042) | (0.039)   | (0.034) | (0.019) | (0.022)   |
|                     | [357]   | [224]     | [194]   | [209]   | [536]     |
| <b>Triplet 3</b>    | 0.010   | 0.084     | -0.025  | 0.009   | 0.011     |
| Community 7         | (0.037) | (0.060)   | (0.055) | (0.042) | (0.034)   |
|                     | [437]   | [182]     | [166]   | [172]   | [472]     |
| <b>Triplet 4</b>    | -0.038  | 0.016     | -0.091  | 0.042   | -0.009    |
| Community 12        | (0.061) | (0.049)   | (0.057) | (0.053) | (0.036)   |
|                     | [219]   | [159]     | [133]   | [125]   | [355]     |
| <b>South Africa</b> |         |           |         |         |           |
| <b>Triplet 5</b>    | -0.042  | -0.250*** | 0.003   | -0.064  | -0.113*** |
| Community 15        | (0.035) | (0.057)   | (0.057) | (0.041) | (0.034)   |
|                     | [367]   | [195]     | [148]   | [162]   | [481]     |
| <b>Triplet 6</b>    | -0.006  | 0.008     | 0.023   | 0.007   | 0.014     |
| Community 17        | (0.015) | (0.010)   | (0.026) | (0.009) | (0.010)   |
|                     | [402]   | [225]     | [155]   | [176]   | [494]     |
| <b>Triplet 7</b>    | -0.008  | -0.007    | 0.081*  | -0.028  | 0.024     |
| Community 21        | (0.027) | (0.018)   | (0.041) | (0.038) | (0.023)   |
|                     | [335]   | [176]     | [203]   | [181]   | [490]     |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses. Observation count in brackets.

**Table 55**

*Health Inequity Index by Wave – Treated Ranked by  
Baseline Wealth*

|                     | (W1)     | (W2)     | (W3)    | (W4)     | (W2–4)   |
|---------------------|----------|----------|---------|----------|----------|
| <b>Zambia</b>       |          |          |         |          |          |
| <b>Triplet 1</b>    | 0.178**  | 0.219**  | 0.187*  | 0.096    | 0.196*** |
| Community 1         | (0.082)  | (0.101)  | (0.112) | (0.129)  | (0.068)  |
|                     | [193]    | [143]    | [123]   | [107]    | [329]    |
| Community 2         | -0.002   | 0.035    | 0.149   | 0.124    | 0.107    |
|                     | (0.043)  | (0.096)  | (0.110) | (0.096)  | (0.067)  |
|                     | [216]    | [124]    | [115]   | [107]    | [291]    |
| <b>Triplet 3</b>    | 0.018    | -0.023   | -0.038  | 0.078    | 0.025    |
| Community 8         | (0.057)  | (0.094)  | (0.130) | (0.096)  | (0.063)  |
|                     | [280]    | [147]    | [130]   | [135]    | [371]    |
| Community 9         | -0.076   | 0.129    | -0.069  | 0.085    | 0.056    |
|                     | (0.071)  | (0.102)  | (0.101) | (0.119)  | (0.068)  |
|                     | [269]    | [125]    | [134]   | [114]    | [319]    |
| <b>Triplet 4</b>    | 0.235*** | 0.163**  | 0.154*  | 0.143    | 0.187*** |
| Community 10        | (0.061)  | (0.079)  | (0.081) | (0.088)  | (0.053)  |
|                     | [337]    | [207]    | [210]   | [177]    | [510]    |
| Community 11        | 0.019    | 0.190*   | 0.065   | 0.133    | 0.134**  |
|                     | (0.073)  | (0.097)  | (0.077) | (0.088)  | (0.056)  |
|                     | [215]    | [132]    | [176]   | [147]    | [388]    |
| <b>South Africa</b> |          |          |         |          |          |
| <b>Triplet 5</b>    | 0.126**  | 0.105    | 0.188** | 0.195*** | 0.152*** |
| Community 13        | (0.057)  | (0.070)  | (0.075) | (0.074)  | (0.046)  |
|                     | [428]    | [267]    | [250]   | [240]    | [689]    |
| Community 14        | 0.022    | 0.181*** | 0.033   | 0.176**  | 0.118*** |
|                     | (0.054)  | (0.060)  | (0.066) | (0.073)  | (0.041)  |
|                     | [335]    | [236]    | [209]   | [171]    | [539]    |
| <b>Triplet 6</b>    | 0.197*** | 0.212*** | 0.166** | 0.101    | 0.135*** |
| Community 16        | (0.053)  | (0.071)  | (0.078) | (0.072)  | (0.043)  |
|                     | [372]    | [195]    | [192]   | [211]    | [548]    |
| Community 18        | 0.139*** | 0.006    | 0.125** | 0.090    | 0.057    |
|                     | (0.049)  | (0.062)  | (0.061) | (0.072)  | (0.041)  |
|                     | [414]    | [221]    | [212]   | [212]    | [564]    |
| <b>Triplet 7</b>    | 0.139*** | 0.117**  | 0.045   | 0.113    | 0.100*** |
| Community 19        | (0.044)  | (0.048)  | (0.054) | (0.069)  | (0.036)  |
|                     | [345]    | [234]    | [214]   | [190]    | [553]    |
| Community 20        | 0.131*** | 0.084*   | 0.055   | 0.086*   | 0.059*   |
|                     | (0.039)  | (0.043)  | (0.050) | (0.052)  | (0.031)  |
|                     | [338]    | [280]    | [260]   | [193]    | [642]    |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses. Observation count in brackets.

**Table 56**  
*Health Inequity Index by Wave – Control Ranked by  
Baseline Wealth*

|                     | (W1)     | (W2)    | (W3)     | (W4)    | (W2–4)   |
|---------------------|----------|---------|----------|---------|----------|
| <b>Zambia</b>       |          |         |          |         |          |
| <b>Triplet 1</b>    | 0.180*** | 0.028   | 0.072    | 0.113   | 0.091*   |
| Community 3         | (0.068)  | (0.072) | (0.080)  | (0.071) | (0.047)  |
|                     | [357]    | [224]   | [194]    | [209]   | [536]    |
| <b>Triplet 3</b>    | 0.048    | 0.200** | 0.139    | 0.102   | 0.123**  |
| Community 7         | (0.053)  | (0.086) | (0.092)  | (0.082) | (0.054)  |
|                     | [437]    | [182]   | [166]    | [172]   | [472]    |
| <b>Triplet 4</b>    | 0.056    | 0.221** | 0.208*   | 0.038   | 0.190*** |
| Community 12        | (0.083)  | (0.094) | (0.111)  | (0.105) | (0.064)  |
|                     | [219]    | [159]   | [133]    | [125]   | [355]    |
| <b>South Africa</b> |          |         |          |         |          |
| <b>Triplet 5</b>    | 0.010    | -0.026  | 0.129    | 0.162*  | 0.069    |
| Community 15        | (0.061)  | (0.093) | (0.100)  | (0.087) | (0.058)  |
|                     | [367]    | [195]   | [148]    | [162]   | [481]    |
| <b>Triplet 6</b>    | 0.030    | 0.002   | 0.235*** | -0.020  | 0.051    |
| Community 17        | (0.052)  | (0.070) | (0.089)  | (0.085) | (0.050)  |
|                     | [402]    | [225]   | [155]    | [169]   | [494]    |
| <b>Triplet 7</b>    | -0.009   | -0.007  | 0.081*   | -0.028  | 0.024    |
| Community 21        | (0.030)  | (0.018) | (0.041)  | (0.038) | (0.023)  |
|                     | [335]    | [176]   | [203]    | [181]   | [490]    |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses. Observation count in brackets.

**Table 57**

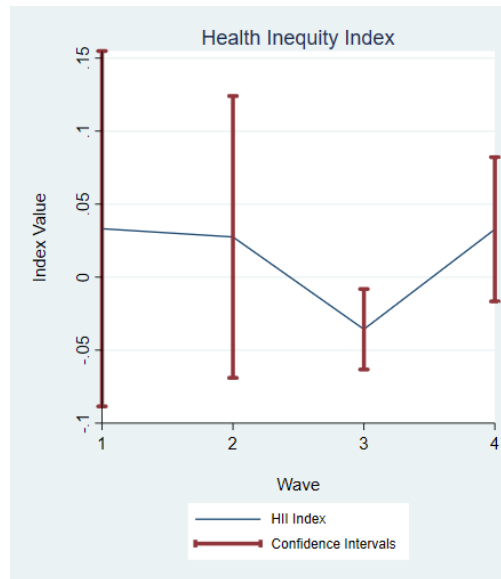
*Difference in Means T-Tests by Wave – Ranked by  
Baseline Wealth*

|                        | (W1)              | (W2)              | (W3)                              | (W4)              |
|------------------------|-------------------|-------------------|-----------------------------------|-------------------|
| HII                    | 0.033<br>(0.047)  | 0.028<br>(0.038)  | <b>-0.036**</b><br><b>(0.011)</b> | 0.033<br>(0.019)  |
| CI, Health Need        | -0.014<br>(0.024) | -0.018<br>(0.034) | -0.018<br>(0.026)                 | -0.008<br>(0.027) |
| CI, Health Utilisation | -0.018<br>(0.029) | 0.023<br>(0.053)  | -0.001<br>(0.020)                 | 0.021<br>(0.022)  |
| N                      | 6                 | 6                 | 6                                 | 6                 |

Note: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Standard errors in parentheses, collapsed at triplet level.

**Figure 39**

*Health Inequity Index Confidence Intervals Estimated with  
Baseline Wealth*



Notes: Tests for difference in means between treated and control populations.

## **7.4 Appendix D: Additional Data, Methods, and Results for Chapter 4**

*All tables on the pages following are referred to within the document.*

**Table 58***Regression Results – Policy by Wave*

|         | (EQ5D)            | (Oolself)          | (Oolact)            | (Oolpain)         | (Oolanx)           | (Oolmob)           |
|---------|-------------------|--------------------|---------------------|-------------------|--------------------|--------------------|
| post    | 0.004<br>(0.003)  | -0.014<br>(0.011)  | -0.014<br>(0.012)   | -0.013<br>(0.017) | -0.025<br>(0.015)  | -0.011<br>(0.011)  |
| policy1 | -0.004<br>(0.003) | 0.017<br>(0.012)   | 0.022<br>(0.014)    | 0.020<br>(0.012)  | 0.011<br>(0.035)   | 0.018<br>(0.009)   |
| policy2 | -0.007<br>(0.004) | 0.018<br>(0.014)   | 0.027<br>(0.018)    | 0.042<br>(0.028)  | 0.040<br>(0.045)   | 0.023<br>(0.015)   |
| policy3 | -0.005<br>(0.004) | 0.016<br>(0.014)   | 0.020<br>(0.016)    | 0.015<br>(0.032)  | 0.043<br>(0.045)   | 0.015<br>(0.011)   |
| wealth  | -0.000<br>(0.000) | -0.000<br>(0.001)  | -0.000<br>(0.002)   | 0.005<br>(0.004)  | 0.001<br>(0.004)   | -0.000<br>(0.001)  |
| working | 0.001<br>(0.000)  | -0.005*<br>(0.002) | -0.006**<br>(0.002) | -0.001<br>(0.005) | -0.008*<br>(0.003) | -0.003*<br>(0.001) |
| wave    | 0.001<br>(0.001)  | -0.002<br>(0.002)  | -0.005<br>(0.003)   | -0.010<br>(0.011) | -0.011<br>(0.008)  | -0.003<br>(0.004)  |
| N       | 102,329           | 102,564            | 102,550             | 102,546           | 102,508            | 102,467            |

Notes: \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . All models include fixed effects. The most complete specification is the following: xtreg depvar post evertreated policy1 policy2 policy3 triplet education wealth sex working, fe vce(cluster triplet)

***One last note of thanks to Dr Marisa Miraldo and Dr Katharina Hauck,  
and to my lovely C, M & C.***