Mortality inequality by municipal income levels: trends in post-apartheid South Africa

Erasmus University Rotterdam

Master Thesis Health Economics

Name Student:	Karel Haal
Enrolled in:	Erasmus School of Economics (ESE)
Student ID number:	432576
Date Thesis:	1-Mei-2017
Name Supervisor:	Dr. Eddy van Doorslaer

Abstract:

Post-apartheid South Africa has placed much focus on reducing inherited disparities in health. In this paper, we use the 2001 and 2011 national Censuses in combination with the 2007 Community Survey to examine whether South Africa, in an era characterized by the rise and fall of the communicable diseases HIV/AIDS and TB, succeeded in redistributing health. In assessing changes in mortality inequality, we rank municipalities by their adult-equivalent per capita income. After splitting these ranked municipalities in groups of equal size, age- and sex specific mortality rates are calculated for each municipality group. Using various health inequality measures, our findings imply that between 2001 and 2011, mortality and absolute mortality inequality increased until 2006, and declined afterwards. Relative mortality inequality, on the other hand, remained mostly stable over the 2001-2011 period. The analysis of age-specific mortality rates shows that for adults aged 18 years and older, mortality and absolute inequality increased substantially between 2001 and 2006, followed by a decrease in the period thereafter. Moreover, we reveal that for the population aged 0-5 and 19-39 year, relative inequality increased between 2006 and 2011. Thus, our results suggest that South Africa's dedication to tackle health disparities has had mixed successes.

Keywords: South Africa, Mortality Inequality, Trend Analyses, HIV, ART

Introduction:

Despite over two decades of structural reform and a relatively high level health spending, South Africa's health outcomes remain rather poor. Compared to other middle-income countries, it performs worse in terms of age-adjusted death rates, years of life lost caused by premature death, and life expectancy at birth (Mayosi & Benatar, 2014). In addition, South Africa accounted for 19% of the global burden of human immunodeficiency virus (HIV) infection in 2015 (UNAIDS, 2016), and is estimated to have the world's highest incidence of tuberculosis (TB) (WHO, 2016). Encouragingly, results of the recently published second National Burden of Disease (NDB) mortality study show signs of improvement (Pillay-van Wyk et al., 2016). HIV/AIDS and TB mortality trends appear to have reversed since 2006. Furthermore, the number of deaths caused by non-communicable diseases (NCDs) has gradually decreased since 2003, maternal conditions have improved from 2009 onward, and the number of injury-related deaths has also decreased.

Whilst changes in South Africa's disease burden have been widely examined, far more limited information is available regarding progress of South Africa's post-apartheid objective of reducing disparities in health. The majority of health inequality related studies have focused on a specific set of diseases and single points in time (Cockburn et al., 2012; Doolan, Ehrlich & Myer, 2007; Harling, Ehrlich & Myer, 2008; Myer, Stein, Grimsrud, Seeda, Williams, 2008; Nkonki et al., 2011; Zere & McIntyre, 2003), considered only a part of the population (e.g. adults or females only) (Ataguba, Akazili & McIntyre, 2011; Wabiri et al., 2016), and, in conjunction, have often used the more contentious, self-assessed measure of health as a health indicator (Ataguba et al., 2015; Wabiri et al., 2013). No nationwide evidence is available on changing disparities in mortality by income. By using two rounds of national Censuses (2001 and 2011), in combination with the 2007 Community Survey (CS), we can fill this gap, as the Census and CS datasets consist of national, individual-level and small geographical-level data on both mortality and indicators of economic status, like income. Moreover, we are able to assess changes in mortality rates across three points in time. Hence, to our knowledge, we are the first to provide evidence on whether South Africa, has managed to reduce disparities in health in an era characterized by the rise and fall of the infectious diseases HIV/AIDS and TB.

The primary objectives of this paper are, therefore, first to investigate overall changes in absolute and relative mortality inequality by municipality income levels in post-apartheid South Africa and second, to identify how trends in mortality inequality differ by gender and age. This information can be used to help guide health system resources and policy initiatives to reduce disparities in health.

The remainder of this paper is structured as follows: the first section reviews relevant background information concerning health inequality in South Africa, mostly focusing on the 2001-2011 period. The second section describes the data and the methodology used, followed by section three, which outlines the results. The fourth section consists of a discussion of the findings, including limitations and implications for future research, while we conclude in the final section.

1 Background

In 1994, South Africa was a fractured nation. Its history of colonial occupation and apartheid had shaped a society into one largely divided by race, gender and geography. Infant mortality among black Africans[1] was five times higher than among Whites and years of underinvestment had divided the health care system along similar racial lines (McIntyre & Gilson, 2001). Consequently, when apartheid ended, Mandela's democratically elected ANC administration was determined to tackle the legacy of disparities. Through the Reconstruction and Development Program of 1994, many pro-equity policies and programs were initiated (Delobelle, 2013). Central to the health and welfare policies was, for instance, the development of a more equitable national health care system (Terreblanche, 2002). In the period that followed, health equity remained high on the political agenda, as indicated by the passing of National Health Act No 61 in 2003, which aimed to improve quality, equitable access, efficiency, and effectiveness of the health system (NDOH, 2004).

1.1 HIV/AIDS and TB

During the transition from apartheid to democracy, efforts in narrowing down health disparities were hampered by the emergence of HIV/AIDS and the colliding TB epidemic. According to surveys conducted among first-time pregnant women who visited public clinics, HIV prevalence increased exponentially from 0.8% in 1990 to 10.4% in 1995 (Gouws & Karim, 2010), to as much as 29.5% in 2011 (NDOH, 2013). Similarly, driven by the emergence of HIV, the incidence of TB had almost tripled from 269 cases per 100,000 population in 1996, to 802 per 100,000 in 2009 (NDOH, 2007; NDOH, 2012). Largely due to inequitable exposures that affect health and the risk of acquisition of HIV, the effect of HIV/AIDS and TB has been greatest among black Africans (Oni & Mayosi, 2016), who make up 80.6% of the population (Stats SA, 2017a)

The initial national response to the HIV/AIDS epidemic, which was marked by denialism and lack of political will, resulted in a substantial burden of ill health and hundreds of thousands of lives lost (Karim, Churchyard, Karim & Lawn, 2009; Coovadia, Jewkes, Barron, Sanders & McIntirye, 2009). Only in 2003, after prolonged national and international criticism, the Mbeki government decided to provide antiretroviral therapy (ART) free of charge (Karim et al., 2009). After a slow start, the rollout of ART was massively scaled-up from 2005 onwards, with support from international donors such as PEPFAR and the Global Fund (Simelela & Venter, 2014). The response against HIV further intensified through the 2007-2011 National Strategic Plan for HIV & AIDS and gained renewed focus in 2009 with the installation of Jacob Zuma and his appointed Minister of Health, Dr Aaron Motsoaledi. In parallel, the National Tuberculosis Strategic of 2007-2011 was launched, which aimed to provide TB patients access to effective, efficient, and high-quality care (Karim et al., 2009).

The HIV/AIDS and TB programs described were not without success. According to Johnson's (2012) findings, almost 1.8 million people received ART's in 2011 versus an estimated 47,500 in 2004. The decline in HIV/AIDS and TB mortalities since 2006, observed in various studies (Bradshaw et al., 2016; Johnson, 2014; Pillay-van Wyk et al.,2016) has been attributed to these intensified ART rollouts (Larson et al., 2012; Pillay-van Wyk et al., 2016). Furthermore, the percentage of undiagnosed HIV-positive adults has decreased from over 80% in the early 2000s to 23.7% in 2012 (Johnson, Rehle, Jooste & Bekker, 2015). With regards to TB, Churchyard et al. (2014) state that efforts of the National Tuberculosis Programs have contributed to a decline in TB case notifications since 2009, as well as improved treatment success rates of new infectious TB cases, which increased from 63% in 2000 to 77.1% in 2011 (NDOH, 2012). Similarly,

[1] The terms 'black African', 'White', 'Colored' and 'Indian' indicates South Africa's racial categorization in terms of the former Population Registration Act. In South Africa, the term 'Colored' refers to those of mixed race descent and has a distinct cultural meaning. The use of such racial terminology here does not imply its legitimacy. Rather, it serves to identify and highlight continuing inequities and vulnerabilities due to the system of apartheid.

'Findings from Death Notifications', published annually by Statistics South Africa, suggests that the number of deaths caused by TB increased between 2001 to 2006, and decreased over the 2006-2011 period (Stats SA, 2005; Stats SA, 2008; Stats SA, 2014).

1.2 Changing Disease Burden

In addition to HIV/AIDS and TB, which, combined, are responsible for 34.1% of total deaths, South Africa's general mortality profile is made up of NCDs, pre-transitional diseases[2] and injuries (Pillay-van Wyk et al., 2016). Similar to HIV/AIDS and TB, other contributors to the so-called 'quadruple' disease burden experienced substantial changes over the 2001-2011 period. First, NCDs, traditionally seen as conditions of the more affluent have been increasingly reported by lower socio-economic groups (Ataguba, Akazili & McIntyre, 2011), and are on the rise in rural communities (Mayosi et al., 2009). Moreover, Nojilana et al. (2016) reported a decrease in age-sex standardized death rates for the on average richer Indian and Colored population in the 2001-2010 period. Overall, according to the findings of Pillay-van Wyk et al. (2016), death rates caused by NCDs have declined since 2003. Second, changes in pre-transitional diseases balanced each other out over time, resulting in an overall stable mortality rate for this group (Pillay-van Wyk et al., 2016). For example, the number of maternal deaths in live births increased until 2009, and decreased thereafter (Stats SA, 2015). Similar reversals have been observed for infant deaths since 2005 (Mayosi & Bentanar, 2014) and infectious and parasitic related deaths since 2010 (Pillay-van Wyk et al., 2016). Furthermore, nutritional deficiencies have steadily declined over the 2000-2011 period (Pillay-van Wyk et al., 2016). Finally, findings from the second NDB study also suggest that death rates from violence and injuries have started to decline since 2005.

1.3 Disparities in Health Care

South Africa's post-apartheid efforts in creating a more equitable health care system have been less successful, or as stated by the National Department of Health in 2011 (NDOH, 2011): '*Post 1994 attempts to transform the healthcare system and introduce healthcare financing reforms were thwarted. This has entrenched a two-tiered health system, public and private, based on socioeconomic status and it continues to perpetuate inequalities in the current health system'.* In other words, racial discrimination in access to care had been replaced by discrimination on economic grounds. These economic disparities are evident in the annual per capita expenditure on health, which is approximately $1,400 in the private sector and $140 in the public sector (Mayosi & Bentanar, 2014). Likewise, although private health insurance covers only 16 percent of the population, it accounts for 44 percent of South Africa's total health-care financing (Mills et al., 2012). Another problematic difference is the skewed distribution of human resources to the advantage of the private sector. One specialist doctor in the private sector, for instance, serves less than 500 people versus 11,000 in the public sector (McIntyre et al., 2007). In addition, public health facilities often have run-down infrastructure, a shortage of essential medication and patients who report long waiting times, as well as staff rudeness (Section27, 2013; Burger, Bredenkamp, Grobler & van der Berg, 2012).

Although public primary health care is free of charge in South Africa, disparities in access to care within the public system also exist. Indirect costs such as travel expenses have, for example, been shown to be substantially higher for people living in rural areas (Goudge, Gilson, Russell, Gumede & Mills, 2009; Harris et al, 2011; McLaren, Ardinton & Leibbrandt, 2014). Encouragingly, results from Harrison (2009) and Burger et al. (2012) suggest that in the post-apartheid era, South Africa's public health care system has made improvements in terms of access. This progress is most likely due to the redistribution of resources between levels of care and between geographical areas (McIntyre et al., 2007), as well as an increase in real per capita public spending on health care since 2000 (Harrison, 2009).

---

[2] Pre-transitional diseases are conditions related to poverty and underdevelopment. This group includes communicable diseases, maternal and child health, and nutritional deficiencies (Bradshaw et al., 2003).

Table 1 Changes in Social Determinants of Health

Domain	2000-2002	2006	2011
Economics:			
▪ Poverty Headcount ($2) (in millions)[a]	33.5 (2000)	27.2	20.8
▪ Income Inequality (measured by GINI) [a]	0.70 (2000)	0.72	0.69
▪ Unemployment (%) (Broad definition) [b, c]	36.1% (2001)	35%	35.6%
Social Protection:			
▪ % of individuals covered by a medical aid scheme[d]	15.9% (2002)	14.2%	16.5%
▪ Social Grant holders (in millions)[a]	3.9 (2001)	9.4	14.9
Education			
▪ % of individuals older than 20 years who received no schooling [a]	11.8% (2002)	10.5%	8.0%
▪ Adult Literacy Rate [b]	72.7% (2002)	76.3%	82.3%
▪ Secondary School Completion (%) [a]	35.6% (2002)	37.5%	43.9%
Household Infrastructure:			
▪ % of households with access to improved drinking water sources [e]	88.2% (2002)	92.5%	93.1%
▪ % of households with access to improved sanitation facilities [e]	62.3% (2002)	70.4%	76.0%
▪ % of households with access to electricity [a]	76.8% (2002)	80.7%	82.8%

Sources: [a] (Stats SA, 2013), [b] (DOBE, 2014), [c] (DPME, 2014), [d] (Stats SA, 2015a), [e] (Stats SA, 2016),

1.4 Social Determinants of Health

To gain a better understanding on the dynamics of mortality outcomes in the 2001-2011 period, it is necessary to expand our focus beyond health care and access to health services. Globally, it is recognized that social and economic conditions outside the health sector are of equal importance to health outcomes than conditions in the health sector (Deaton, 2002). Furthermore, besides having an impact on absolute health, Ataguba et al. (2015) show that social protection and employment, knowledge and education, and housing and infrastructure contribute substantially to disparities in self-assessed health in South Africa. To provide more context on these so-called social determinants of health, we briefly summarize South Africa's progress with improvements in these determinants (see Table 1).

In the first decade of the 21th century, substantial economic progress was made in South Africa. The GDP growth rate averaged around 3.6% per year (DPME, 2014), and the number of people that lived on less than $2 a day decreased from approximately 33.5 million in 2000 to 20.8 million in 2011 (Table 1). The vast expansion of social grants since 1997 has contributed to this reduction in poverty headcount (Mayosi & Benatar, 2014). Similarly, access to and the completion of basic education has improved, as has access to water, sanitation and electricity. Nonetheless, wide inequalities in South Africa's social determinants of health persist. Income inequality remains among the highest in the world (World Bank, 2017), unemployment rates have not improved, and limited progress in reducing gender inequality has been made (UNDP, 2014).

1.5 Health Inequality Literature

South Africa's history of social inequality, its post-apartheid objective of reducing health disparities, and the relentless burden of HIV/AIDS and TB deaths have all contributed to wide interest in the distribution of health. Consequently, a substantial number of studies have examined South Africa's health inequality situation.

A commonly used approach in assessing health inequality is the so-called univariate analysis, in which the distribution of other socio-economic status (SES) indicators is not controlled for (Wolfson & Rowe, 2001). In South Africa, findings from the second NDB, for example, suggest that the 2005 all cause age-standardized death rate in the province KwaZulu-Natal was twice as high as in the Western Cape (Pillay-van Wyk et al., 2016). Likewise, infant mortality rates in 2005 were found to be four times higher on average among black people than among white people (Benatar, 2013), and black Africans reported significantly lower health levels than Whites in 1999 (Charasse-Pouélé & Fournier, 2006).

In contrast, in bivariate analysis the distribution of health is conditional on income or other SES indicators (Wolfson & Rowe, 2001). Most bivariate studies conducted in South Africa find evidence for the existence of a 'health gradient'. This gradient implies that individuals of lower SES have worse health than individuals with a higher socio-economic background (Deaton, 2002). For example, a group of studies which focused on specific parts of South Africa's morbidity burden, showed that SES is inversely associated with self-reported TB (Harling, Ehrlich & Myer, 2008), psychological distress (Myer, Stein, Grimsrud, Seeda, Williams, 2008), violence (Doolan, Ehrlich & Myer, 2007), vision loss (Cockburn et al., 2012), infant mortality (Nkonki et al., 2011) and with rates of stunting and underweight among children under-five (Zere & McIntyre, 2003). Similar, studies which considered the full morbidity burden, by using self-assessed health (SAH) as a measure of health, showed that good SAH is more concentrated among the rich (Wabiri et al., 2013; Ataguba et al., 2015).

However, the above literature is restricted to single points in time. Studies which assess changes over time are relatively scarce. Ataguba, Akazili and McIntyre (2011) argue that they were the first to conduct a bivariate trend analysis for the relationship between SES and health in South Africa. Using data from the South African General Household Surveys in the 2002-2008 period, the authors examined a wide range of self-reported illnesses and disabilities against a composite index of SES. Their results suggest that inequality in self-reported TB and HIV by SES increased until 2006, and decreased thereafter (although it remained concentrated among the poor). A second study compared equity in maternal health in 2008 and 2012 using serial National Household Surveys (Wabiri et al., 2016). According to their findings, inequalities in self-assessed maternal health by SES narrowed both in absolute and relative terms. However, because these trend analyses focused either on specific parts of the population (adults or females only) or disease burden, they were unable to capture the full extent of changes in South Africa's distribution of health.

In addition to constraints in the considered disease burdens, population and time, South Africa's literature on socio-economic inequalities in health is subject to another important limitation: the exclusive reliance on measures of self-reported illnesses and SAH. Even though robust correlations have been found between SAH and actual mortality, the use of the subjective SAH measure as an indicator of health remains ubiquitous (e.g. Idler, Russell & Davis, 2000; Idler & Benyamin, 1997; Doorslaer & Gerdtham, 2003). A main reason for concern is that the self-reporting of health may be systematically biased by socio-economic characteristics. In South Africa, Rossouw (2015), for example, found that the poor use different reporting scales than the more affluent, resulting in under-reporting of poor health.

2 Data and Methods

As mentioned in the introduction, to assess changes in mortality inequality, we apply a similar method as Currie and Schwandt (2016) who examined the distribution of life expectancy and mortality in the United States. Rather than considering differences in mortality by education or relative income level, they ranked groups of counties by their poverty rates. Their main reason for pursuing a geographical approach was a lack of individual level data on both income and health status. Clustering data in geographical areas allowed them to overcome this issue, as mortality data, the population count and average poverty rates were available at the county level. Additional reasons for using a geographical approach are detailed in their study. In brief, studies which examine mortality inequality by relative income are subject to possible reverse causality between income and health. For mortality inequality by education studies, concerns exist around compositional changes of education groups over time. Moreover, a geographical approach is of interest for its own sake, as previous research has found striking associations between certain geographical features and people's health. For example, Chetty et al. (2016) show that low-income individuals in the US tend to live longest in cities with highly educated populations, high incomes, and high government expenditures. For these reasons, together with the fact that we did not have individual mortality and income data available on the same sample population in 2011, we decided to adopt a similar geographic strategy to assess mortality inequality. However, mainly due to differences in data availability between the United States and South Africa, several alterations had to be made regarding Currie and Schwandt's approach. A description of the data sources and methodology is given next.

2.1 Data Sources

Ideally, mortality rates are estimated directly from vital registrations of births and deaths. However, the quality of death administrations in low and middle-income countries is often not sufficient to provide reliable mortality estimates (Nannan et al., 2012). In South Africa, Pillay et al. (2014), for instance, estimated that in 2001, only 61% of all infant deaths were registered. Second, as in most other countries, vital registrations in South Africa do not include information on income. Third, data on registered deaths at a small geographical level, necessary for our approach, is not publicly available. Alternative mortality sources in South Africa that do consist of individual data on both mortality and SES, at a small geographical level, are sample surveys and censuses. For this reason, we use the 10% sample data that is made publicly available from the 2001 and 2011 Census, in combination with the full (100%) 2007 CS data, to assess changes in mortality inequality.[3]

Historically, Censuses in South Africa are conducted at 5 year intervals (1996-2001). However, due to capacity constraints, the Cabinet decided to expand the interval to 10 years, with a large-scale household survey designed to provide similar information to the Censuses (Stats SA, 2007) in-between censuses. As a result, the scope of the CS 2007, often referred to as mini-Census, is of considerable size, but much smaller than the 2001 and 2011 censuses (Table 2). Furthermore, while full 2001 and 2011 census data is not publicly available, we were forced to use 10% sample datasets. For both years, the 10% dataset was sampled by drawing a 10% sample from all surveyed households. The individual 10% sample consists of persons living within the 10% sampled households. In all our analysis, only the population living in housing units (and converted hostels in 2011) is considered. Persons enumerated in institutions were excluded as no mortality questions were asked in institutions[4].

The 2001 Census sample had a high proportion of missing values in key indicators such as gender (1.3%), education (6.6%) and income (15.6%). As a consequence, the 10% sample dataset published by Stats SA consists of observations for which missing values have already been imputed (Barnes, Gutierrez Romero & Noble, 2006). However, Stats SA imputation methods[5] have led to an implausible high proportion of households (23%) with zero household income (Ardington, Lam, Leibbrandt & Welch, 2006). As a result, researchers at the Centre for the Analysis of South African Policy (CASAPS) at the University of Oxford, applied a different imputation technique of which the results are publicly available (Barnes et al., 2006). After recoding problematic values to missing values following a specific set of rules that are detailed elsewhere (Ardington et al, 2006), the authors applied a sequential multiple regression imputation technique (SMRI). Since the obtained results provided more plausible results with regarding the zero household incomes (12% vs. 23%), we have used the imputed income data from one of these CASAPS imputation datasets, as well as their imputations for gender and age, for our 2001 analysis.

---

[3] All data was obtained from DataFirst, although all surveys were conducted and released by Statistics South Africa.

[4] Institutions in 2001 and 2011 include: residential/tourist hotel, worker's hostel, hospital/medical facility, orphanage, home for disabled, boarding school, initiation school, convent/monastery, student residence, home for the aged, prison/correctional institution/police cells, defense force barracks and refugee camps/shelter (Stats SA, 2001; Stats SA, 2011). The 2007 CS did not survey people living in institutions (Stats SA, 2007).

[5] Stats SA used a combination of logical and hot-deck imputation procedures. For logical imputations: 'a consistent value is calculated or deduced from other information relating to the individual or household' (Stats SA, 2001). In case a logical imputation was not possible, the hot-deck procedure was applied: 'Hot deck imputation involves matching as closely as possible individuals with missing data on some variables to individuals who have complete records, and using the information from the latter to replace the missing values in the former' (Stats SA, 2001).

Table 2 Description of variables in study sample

Domain	10% Census 2001	CS 2007	10% Census 2011
General:			
▪ Households Surveyed	905,748	246,618	1,171,116 [a]
▪ Persons surveyed	3,725,665	949,100	4,337,697
▪ % of persons surveyed living in institutions	3.37%	0%	1.7%
▪ Local Municipalities	262	262	234
Demographics of sampled population:			
▪ Population group (%)			
Black African	79.74%	79.82%	80.18%
Colored	9.03%	10.48%	8.75%
Indian or Asian	2.57%	2.18%	2.48%
White	8.67%	7.52%	8.19%
Other	NA	NA	0.41%
▪ Age group (%)			
0-5	12.4%	12.3%	13.3%
6-18	30.0%	30.0%	24.9%
19-39	33.6%	33.4%	35.1%
40-59	16.8%	18.4%	18.6%
60+	7.5%	7.8%	8.2%
▪ Mean Age	26.6	27.4	27.9
▪ Males / Females (%)	46.9% / 53.1%	47.4% / 52.6%	47.9% / 52.1 %
Households:			
▪ Mean HH income (in ZAR) [b]	R 43687	R 73735	R 112045
▪ Median HH income (In ZAR) [b]	R 13576	R 23976	R 27176
▪ Number of HH with zero income	12.2%	7.3%	7.9%
▪ % of missing HH income	(imputed)	1.15%	1.45%
▪ Average HH size	5.62	5.48	5.11
Deaths			
▪ Number of deaths (12-month period)	36,267	14,969	40,303
▪ Minimum # deaths by Mun-age-sex group [c]	144	53	72
▪ Median # of deaths by Mun-age-sex group [c]	447	172	489
▪ Maximum # of deaths by Mun-age-sex group [c]	759	359	828

[a] In addition to the housing units, 23006 converted hostels in the 2011 census been considered. According to Stats SA, a converted hostel is defined as: 'Hostels where the accommodation has been converted into self-contained units for households' (Stats SA, 2011).
[b] Not adjusted for inflation.
[c] Excluding age group 6-18.

2.2 Variables

Health Indicator

Whereas the scope varied between the three surveys, our variables of interest have been collected in consistent ways. Information on mortality, our objective measure of health, was obtained through the question: 'Has any member of this household passed away in the last 12 months? ' (e.g. between 10 Oct 2000 and 10 Oct 2001, Feb 2006 and Mar 2007, 10 Oct 2010 and 9 Oct 2011). As the majority of deaths in the 2007 CS occurred in 2006 (88.9%), we refer to 2006 mortality rates from this point onward, rather than referring to 2007 mortality rates. Furthermore, in 2001, the 10% mortality sample was based on deaths that occurred in the 10% household sample. In contrast, the mortality data in 2011 was sampled differently to that in the household and person sample. Consequently, we had to assume that the 10% mortality sample in 2010 was a random sample of deaths in each municipality. For this reason, as a data reliability check, we examined whether the Census/CS deaths are an accurate representation of deaths by comparing mortality rates obtained from the Censuses/CS with death notifications adjusted for completeness, at the province level. We used adjustments rates derived from Pillay-van Wyk et al. (2016) and alternative mid-year population estimates from Dorrington (2013). The results presented in Appendix A, suggest that at the province level, we would derive similar conclusions in all our analyses if we used death registrations rather than census mortality rates, as they show in most cases (except for age group 60+), similar levels and patterns over time. A further limitation of the data is that both the census and survey mortality data may suffer from recall bias (Timaeus, 1991), as well as possible selection bias since deaths in single member households are not reported (Blacker, 2004). We are not fully able to adjust or control for this and therefore use the data fully aware of its limitations, as it is the best available data.

In our main analysis, mortality rates are separately calculated for the age groups 0-5, 6-18, 19-39, 40-59, 60+ (see distribution Table 2). This categorization was chosen for two reasons. One, except for age group 6-18, it distributes deaths fairly equally over the different age groups[6]. Most municipality-age-sex groups therefore consist of a reasonable number of deaths to provide reliable mortality rate estimates (see Table 2 for the range of the number of deaths for all municipality-age-sex groups by year). Second, the categorization is largely in line with the different impacts HIV/AIDS and TB have had on certain age groups (Bradshaw et al., 2016).

SES Indicator

Due to data availability, we used income, rather than consumption or expenditure, as our SES ranking indicator. The income variable in all cases refers to the adult equivalized income per capita and is given in real terms with 2001 as the base year. Income has been adjusted for inflation by using consumer price indexes published by Stats SA (Stats SA, 2017b). In the 2001 Census, each person was asked: 'What is the income category that best describes the gross income of (this person) before tax?'. Although the income intervals remained the same over the years, the wording and structure of the income question changed in 2007 and 2011 to: 'What is the income category that best describes the gross monthly or annual income of (the person) before deductions *and* including all sources of income?', resulting in a possible underestimation of income in 2001. Annual household incomes were then calculated by adding up incomes of all members of the households. However, since personal incomes were collected in income ranges, fixed amounts had to be allocated first. Allocation rules suggested by Stats SA were used in doing so (Stats SA, 2011). In addition, since Case and Deaton (1998) found evidence for economies of scale in South African households, possibly attributable to bulk purchasing or economies of scale in food preparation, it is necessary to increase the size of welfare measures for larger households relative to smaller households. Although various adult equivalence methods have been used in South Africa (Posel & Rogan, 2014), similar to Leibbrandt, Woolard, Finn & Argent (2010), we computed equivalent adult household income by dividing the annual household income by the square root of household size (of people still alive).

Furthermore, we use municipalities as our geographical level, the smallest level available in the three surveys. In the 2001 Census and 2007 CS, South Africa's geographical framework consisted of 262 local municipalities. This total has been reduced to 234 local municipalities in the 2011 Census. However, due to the fact that we aggregate municipalities into large decile-like categories, the reduction has only a very limited effect on our analysis.[7]

[6] Because deaths are relatively scarce for persons aged 6-18, results for this group have been excluded from our main analysis, but can be found in Appendix C.

[7] For a person who died, the municipality of household residence for a person who died was selected in the 2001 Census and 2007 CS. Due to data restrictions, the municipality where the person had died was selected in the 2011 Census.

2.3 Health Inequality Measurement

Similar to Currie and Schwandt (2016), we use a graphical measure related to the slope index of inequality (SII) to assess absolute inequality (i.e. the magnitude of the difference in health between subgroups). The interpretations of the graphs are described in the results section. While it is important to estimate both absolute and relative differences (Regidor, 2002; WHO,2013), we in addition calculate relative inequality (i.e. the proportional difference in health among socio-economic groups) through health concentration indices (CI), following a method described by Wagstaff et al. (2007). The theoretical value of the CI lies between -1 (when all mortality is concentrated in the poorest subgroups) and +1 (when all mortality is concentrated in the richest subgroups) (Wagstaff, 1991). A value closer to -1 (or +1) implies higher inequality. Besides being the most common measure to summarize health inequality (WHO, 2013), the SII and CI have previously been identified as adequate measurements of health inequality by SES, as they are sensitive to changes in the distribution of the population across socio-economic groups, reflecting the health experiences of the entire population and while they are consistent with ranking units across socio-economic groups (Wagstaff, Pact & Doorslaer, 1991). Finally, we compute a single summary measure proposed by Wagstaff (2002) that reflects both average health and inequality in its distribution. A lower value of this so-called achievement index (AI) reflects better overall 'achievement' in health. The average age-sex specific mortality rates (per 1,000) are used in the AI measure as mean health.

2.4 Methodology

Construction of Municipality Groups

In our main analysis of assessing mortality inequality, we rank municipalities by their average adult equivalent (AAE) per capita income level. The municipalities are then divided in ten groups of similar size, each representing approximately 10 percent of the surveyed population. Hence, the first 'municipality group' consists of the 10 percent living in the poorest municipalities (as measured by AAE level), and the tenth municipality group of the 10 percent of the population living in the richest municipalities. The ranking is done separately for each year, which avoids problems of municipality population shares that change over time, as well as issues around changing income levels in municipalities which affect their income rank (Currie & Schwandt, 2016). Based on the municipality groups, age-gender-specific, one-year mortality rates are constructed. To be specific, we divide the total number of deaths that occurred over a 12 month period before each census/CS by the population surveyed and individuals that died, for each specified group. For example, to derive mortality rates for males aged 0-5 in the poorest municipality group of 2001, we added the total number of deaths that occurred between 10 October 2000 and 10 October 2001 within this group and divided it by the population surveyed plus the number of deaths in this group. Thus, rather than calculating mortality rates separately for each municipality, we calculate mortality rates per municipality group. One of the advantages of grouping mortality within municipality ranks is that it is likely to reduce measurement error, due to the fact that only few deaths occurred in smaller municipalities.

A number of issues arise when splitting municipalities in this way. First, the created municipality groups do not add up to exactly 10% of the population, as the ranked municipalities at the margin may overlap the group size of 10%. This is mainly caused by five larger (and on average richer) municipalities in South Africa: Johannesburg, Cape Town, eThekwini, Ekurhuleni and Tshwane. However, in practice, variation in group size is limited (see Table 3). Second, some of the municipality groups are substantially influenced by a relatively high number of persons surveyed in one of the larger municipalities. For example, in 2011, 98% of 'Municipality Group 9' consists of people surveyed in the City of Cape Town (see Table 3). To overcome these limitations, we have applied an alternative approach the results of which are presented in Appendix B. In short, this 'blended' approach divides the largest municipalities by income in five smaller groups of equal size. As a result, the first group of, for example, the Cape Town municipality, consists of the poorest 20% of the population in the municipality and the fifth group consists of the richest 20%. After that, similar to the original approach, we rank municipalities by their AAE per capita level. Consequently,

Table 3 Overall division of population surveyed across municipality groups

Municipality Group	2001 Census	2007 CS	2011 Census
1	9.7%	9.9%	9.9%
2	9.8%	9.7%	9.9%
3	10.4%	10.4%	10.0%
4	10.0%	10.0%	10.2%
5	9.9%	10.0%	9.5%
6	9.8%	9.2%	10.3%
7	6.7%	7.4%	10.0%
8 [a]	9.4%	9.7%	9.1%
9 [b]	12.6%	11.9%	7.3%
10 [c]	11.7%	11.9%	13.9%

[a] *Group* 8, 2001: 68% eThekwini, 2007: 59% eThekwini 2011: 67% Ekurhuleni

[b] *Group 9*, 2001: 44% Ekurhuleni & 53% Cape Town, 2007: 48% Cape Town & 42% Ekurhuleni 2011: 98% Cape Town

[c] *Group 10*, 2001: 62% Johannesburg & 38% Tshwane, 2007: 57% Johannesburg & 35% Tshwane 2011: 60% Johannesburg & 40% Tshwane

the poorest 20% of Cape Town belongs to the first municipality group, and the richest 20% of Cape Town belongs to the tenth municipality group. Surprisingly, this more refined 'blended' approach does not lead to higher inequality in mortality by income: for example, in 2001 and 2006, we found lower absolute mortality inequality for age groups 0-5, 18-39 and 40-59 using the blended approach, in comparison to the 'original' approach. Nevertheless, in our main analysis, we present results from our original approach, as the blended approach is not possible for 2011. Namely, due to differences in the 2011 CS 10% samples, we do not have individual level information on adult equivalent per capita income of a diseased person. Thus, we cannot distribute deaths across smaller income groups within a municipality.

Full population analysis

Before examining age-gender specific mortality changes, we conduct several full population analyses for the 2001-2011 period. First, through an abridged life table technique described in Chiang (1984), we calculate changes in life expectancy (LE) at birth. Second, using our three datasets, we present changes in income inequality as measured by the Gini coefficient. Rather than plotting the associated Lorenz Curve (LC), we show changes in overall social welfare by using the Generalized Lorenz Curve (GLC), proposed by Shorrocks (1983). This graphical measure plots the cumulative mean of the adult equivalent per capita income variable against the cumulative percentage of population ranked by the same income variable. While the GLC is affected by the mean of the income distribution, the curve would rotate upwards if everyone in the society were to earn twice as much as they previously did, whereas the LC would remain unchanged. Third, after indirectly standardizing the age-sex distribution of mortality, using the method described in Wagstaff et al. (2007), the municipality approach is used to assess overall changes in health inequality. We thereby make use of similar graphs as for the age-gender-specific mortality rates.

3 Results

3.1 Full Population Analysis

Life Expectancy at Birth

Figure 1 presents changes in LE at birth by gender. The plot suggests a drastic decline in LE between 2001 and 2006, for both males and females. However, a relatively larger reduction in LE is observed for females (17.2%) than males (13.6%). After 2006, LE at birth increased again. While the increase over the 2006-2011 period in LE was stronger than the decrease in the 2001-2006 period, LE at birth estimates are higher in 2011 than in 2001,. LE at birth in each year is higher for females than for males, although the gap in LE between males and females varied widely between each year. In 2001, females were expected to live 8.1 years longer than males. This gap reduced to 4.7 in 2006, and increased again to 6.6 in 2011.

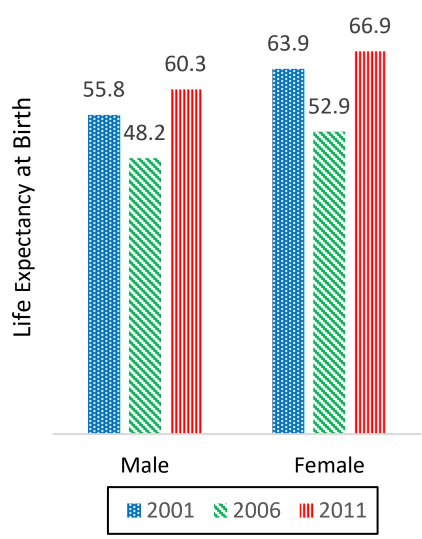
Income Inequality

Turning to income inequality, Figure 2 indicates that relative income inequality as measured by the Gini coefficient slightly decreased from 0.77 in 2001 to 0.75 in 2006, and increased again to 0.76 in 2011. Yet changes were minor, suggesting that income inequality stayed fairly constant over the 2001-2011 period. Although our Gini estimates (2001: 0.77, 2006: 0.75, 2011: 0.76) are near the upper end of South African Gini estimates, our 2001 estimates are, for instance, consistent with the previously estimated 2001 Gini coefficients of 0.76 (Yu, 2009), 0.79 (Leibbrandt et al., 2006) and 0.80 (Ardington et al., 2006). Social welfare on the other hand, as shown by the dominance of the 2006 GLC curve over the 2001 GLC curve in Figure 2, improved substantially over the 2001-2006 period. While income inequality remained constant, the improvement in overall welfare can be largely attributed to an increase in real mean adult equivalized per capita income (from R21225 in 2001 to R27692 in 2006). For the 2006-2011 period, changes in welfare are more ambiguous, as no dominance is observed between the 2006 and 2011. The reason is that although average income increased in this period (R31659 in 2011), relative income inequality became slightly worse.

Mortality and Mortality Inequality

Finally, changes in overall mortality inequality are presented in Figure 3. In this graph (as in Figures 4-7), municipality groups are ranked by their AAE per capita income on the horizontal axis. The vertical axis shows 1 year mortality rates (per 1,000). The squares, diamonds and triangles show the average 1 year mortality rate per municipality group, for 2001, 2006 and 2011 respectively. As discussed earlier, each municipality group consists of approximately 10% of the surveyed population. The short-dashed, solid and long-dashed lines are fitted regressions drawn through these points, again for 2001, 2006 and 2011

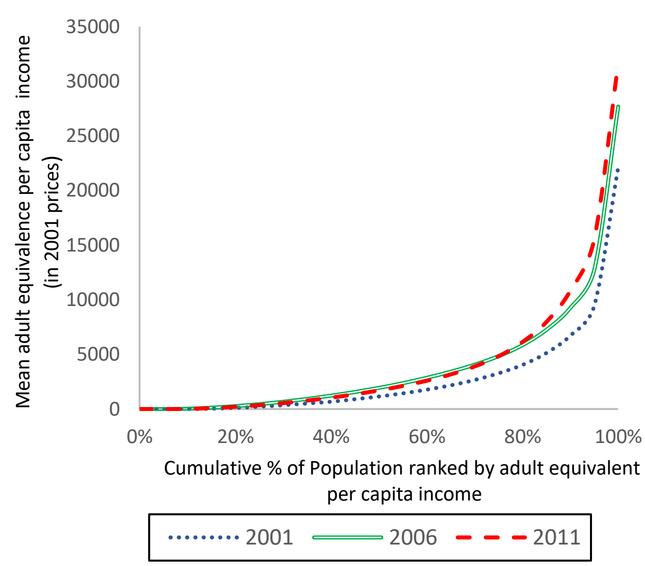
Figure 1 LE at Birth by Gender and Year



*LE: Life Expectancy

Source: Authors using data from 2001 Census, 2007 CS and 2011 Census

Figure 2 Generalized Lorenz Curve by Year



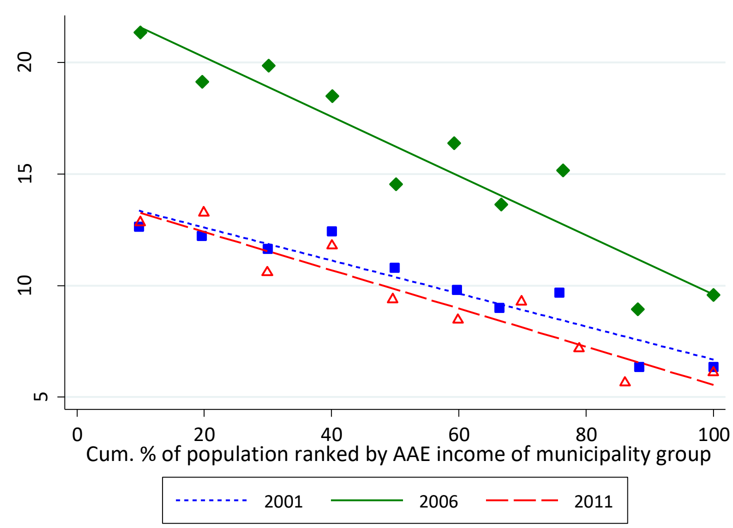
Measure	2001	2006	2011
GINI	0.77	0.75	0.76
Mean AE income (2001 prices)	R 21225	R 27692	R 31659

respectively. A negative slope of the best-fit regression line indicates that mortality rates are higher in poorer municipality groups than in richer municipality groups. When a line becomes steeper over time, it implies that mortality rates have increased more in poorer municipalities than in richer municipalities, and vice versa. Hence, a steeper slope suggests an increase in absolute inequality. Furthermore, if the line of year α always lies above year β, it implies that mortality rates are consistently higher in year α.

In addition to presenting the slopes, exact slope coefficients, information on CI (measure of relative inequality), mean health, AI (measure of health achievement) and p-values of differences in slope between years are given below Figure 3. As mentioned earlier, a negative CI suggests that mortality is more concentrated among the poor. Second, a lower AI implies better overall mortality achievements. Third, the p-value of differences in slope indicates whether absolute inequality was significantly different between two years.

The fact that the 2006 line in Figure 3 is consistently above the 2001 and 2011 line thus suggests that age-sex standardized mortality rates were higher in 2006 than in 2001 and 2011. Furthermore, the significantly steeper line of 2006 implies that absolute mortality inequality deteriorated over the 2001-2006 period, and improved again between 2006 and 2011. Hence, the mortality increase between 2001 and 2006 was greater in poorer municipalities than in richer ones, as was the reduction between 2006 and 2011. Also, our results imply that South Africa had similar levels of mortality and absolute mortality inequality in 2001 and 2011, as no significant differences between the beginning and the end of the first decade of the 21st century were observed. Moreover, the negative values of CI suggest that mortality was relatively more concentrated among poorer municipalities in every year. Although the concentration indices slightly increased over time, the differences are likely insignificant, and we therefore conclude that overall relative inequality stayed largely stable over the 2001-2011 period. Because relative inequality did not change, the observed reversal in overall mortality (both the mean and distribution of mortality) is largely driven by changes in mean mortality.

Figure 3 Age-sex standardized mortality rates across groups of municipalities ranked by income [(a)]



Measure	2001	2006	2011
Slope Index	-0.07**	-0.13**	-0.09**
Concentration Index	-0.13	-0.14	-0.15
Per 1,000 Mortality Rate	10.1	15.7	9.5
Achievement Index	11.4	18.0	10.8

Measure	2001-2006	2006-2011	2001-2011
P-value of difference in slope between years	0.003**	0.015*	0.525

*Significant at 5% level, ** Significant at 1% level

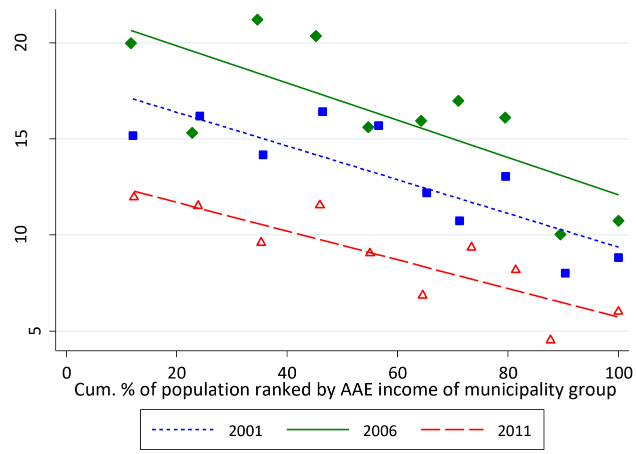
[(a)] The income ranking variable is the municipalities average adult equivalized (AAE) per capita income level

3.2 Age-Sex Specific Mortality Analysis

Using the same graphical measure as in Figure 3, Figures 4-7 present changes in absolute mortality inequality by gender and age group. The p-values of differences in slopes between years and gender are presented in Table 4.

Figure 4 One-year mortality for population aged 0-5 across groups of municipalities ranked by income

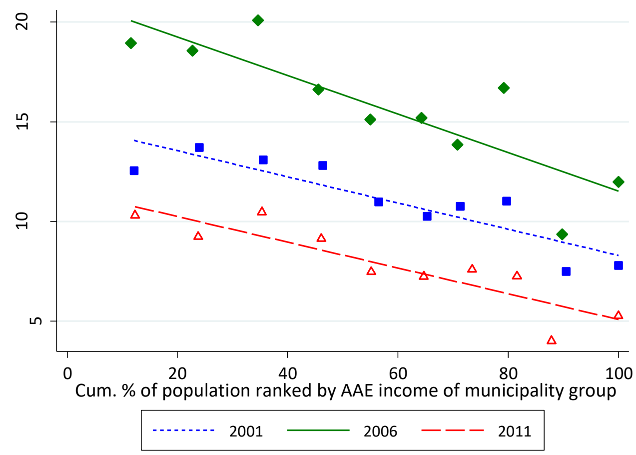
Male 0-5



Measure	2001	2006	2011
Slope Index	-0.09**	-0.10*	-0.07*
Concentration Index	-0.10	-0.10	-0.13
Per 1,000 Mortality Rate	13.04	16.22	8.86
Achievement Index	14.40	17.81	9.99

*Significant at 5% level, ** Significant at 1% level

Female 0-5

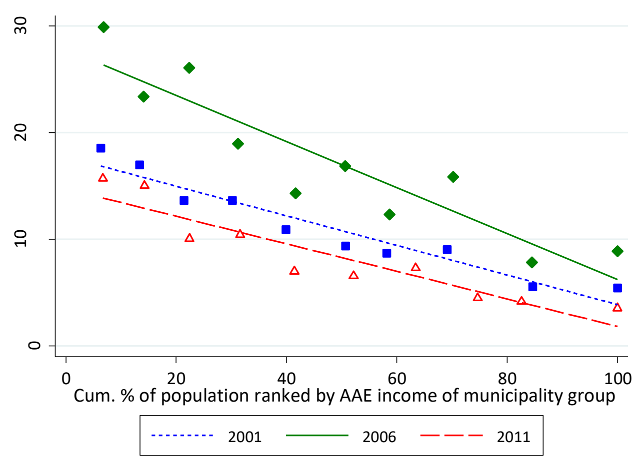


Measure	2001	2006	2011
Slope Index	-0.07**	-0.10**	-0.06**
Concentration Index	-0.09	-0.10	-0.13
Per 1,000 Mortality Rate	11.04	15.64	7.89
Achievement Index	12.09	17.21	8.94

*Significant at 5% level, ** Significant at 1% level

Figure 5 One-year mortality for population aged 19-39 across groups of municipalities ranked by income

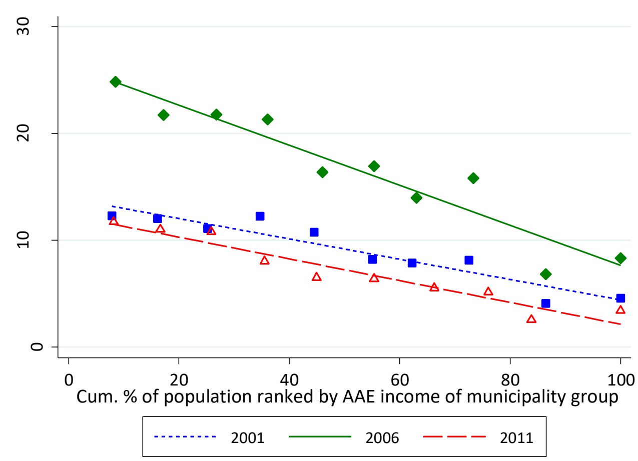
Male 19-39



Measure	2001	2006	2011
Slope Index	-0.14**	-0.22**	-0.13**
Concentration Index	-0.23	-0.22	-0.27
Per 1,000 Mortality Rate	11.19	17.45	8.44
Achievement Index	13.71	21.30	10.70

*Significant at 5% level, ** Significant at 1% level

Female 19-39



Measure	2001	2006	2011
Slope Index	-0.10**	-0.19**	-0.10**
Concentration Index	-0.19	-0.20	-0.25
Per 1,000 Mortality Rate	9.14	16.80	7.39
Achievement Index	10.90	20.16	9.26

*Significant at 5% level, ** Significant at 1% level

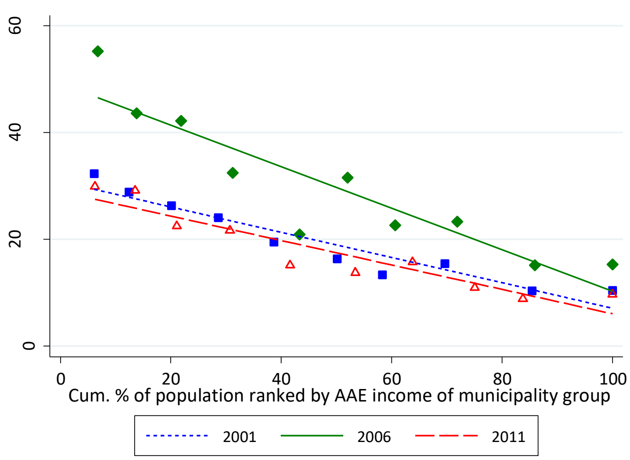
For children between the ages of 0 and 5, figure 4 shows that mortality rates increased in all municipality groups between 2001 and 2006, for both females and males. Since the reduction in mortality rates during the 2006-2011 period have been starker than the increase before 2006, mortality rates in 2011 were lower than in 2001. The significant negative slope implies that under-five mortality is higher in poorer municipalities than in richer municipalities. However, as indicated in Table 4A-4B, the slopes are not significantly different from each other, suggesting that absolute inequality did not change between 2001 and 2011. Relative inequality, on the other hand, increased between 2006 and 2011. Despite this increase in inequality, better mean health resulted in improved overall health outcomes, as measured by the achievement index.

Moving towards age group 19-39, the significantly steeper lines observed for 2006 in Figure 5 imply that absolute inequality worsened over the 2001-2006 period, and improved again after 2011. Interestingly, whereas absolute inequality increased between 2001-2006, relative inequality mainly increased between 2006 and 2011. Furthermore, similar to under-five mortality, females had a lower mortality rate than males. However, whereas average mortality rates increased by about 56% between 2001 and 2006 for males, females saw their mortality increase by 84% over the same period. In contrast, between 2006 and 2011, female mortality rates (-94%) decreased much starker than male mortality rates (52%). Overall, 2011 had the best overall health outcomes for the age group 19-39.

Results for males and females aged 40-59 are presented in Figure 6. Similar to the 19-39 age group, absolute inequality increased for both males and females over the 2001-2006 period, and decreased again after 2006. Relatively inequality on the other hand remained constant for males between 2001-2011, and slightly increased for females over the 2001-2006 period. Results from Table 4C suggest that in age group 40-59, absolute inequality was larger for males than for females. Similarly, relative inequality and average 1-year mortality rates were higher for males than females.

Figure 6 One-year mortality for population aged 40-59 across groups of municipalities ranked by income

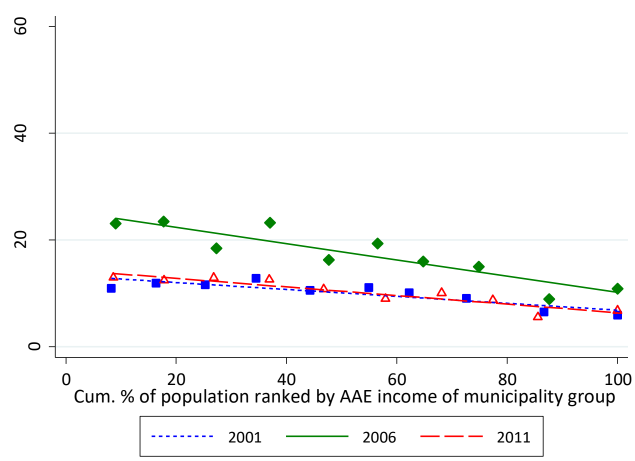
Male 40-59



Measure	2001	2006	2011
Slope Index	-0.24**	-0.39**	-0.23**
Concentration Index	-0.22	-0.22	-0.22
Per 1,000 Mortality Rate	19.71	30.25	17.75
Achievement Index	23.96	37.01	21.66

*Significant at 5% level, ** Significant at 1% level

Female 40-59



Measure	2001	2006	2011
Slope Index	-0.06**	-0.15**	-0.08**
Concentration Index	-0.12	-0.15	-0.14
Per 1,000 Mortality Rate	10.09	17.47	10.33
Achievement Index	11.31	20.15	11.79

*Significant at 5% level, ** Significant at 1% level

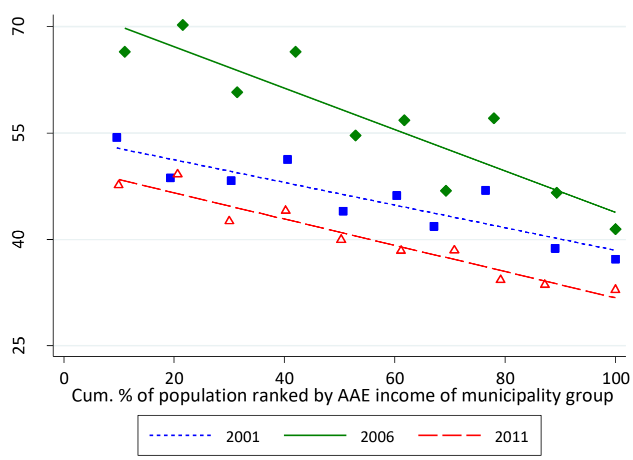
Turning towards the elderly, results for the population aged 60 and older are presented in Figure 7. Whereas for all age categories and sexes mortality rates are higher among poorer municipalities (as indicated by the steeper lines), the flat lines for females aged 60+ suggest that female mortality is equally distributed among municipalities. Nonetheless, Figure 5 suggests that female mortality was higher in 2006 than in 2001 and 2011. For males aged 60+, results indicate that poorer municipalities tend to have higher mortality rates than richer municipalities. Furthermore, the significantly different slopes of 2006 suggest that absolute inequality for males increased between 2001 and 2006, and decreased again over the 2006-2011 period. Absolute inequality was, however, higher for males than females (non-existent). Finally, similar to age group 40-59, overall health achievement improved for males, and slightly worsened for females over the 2001-2011 period.

4 Discussion

This analysis provides new insights into the South African health inequality experience. Our findings indicate that, overall, mortality is concentrated among poorer municipalities. Moreover, we reveal that in the beginning of the new millennium, mortality and the degree of absolute mortality inequality increased until 2006 and afterwards declined to levels similar to those in 2001. Relative inequality, on the other hand, remained mostly stable during the 2001-2011 period.

Figure 7 One-year mortality for population aged 60+ across groups of municipalities ranked by income

Male 60+



Measure	2001	2006	2011
Slope Index	-0.16**	-0.29**	-0.18**
Concentration Index	-0.06	-0.08	-0.08
Per 1,000 Mortality Rate	45.73	56.72	40.10
Achievement Index	48.41	61.50	43.14

*Significant at 5% level, ** Significant at 1% level

Female 60+

Measure	2001	2006	2011
Slope Index	0.03	0.02	-0.03
Concentration Index	0.01	0.01	-0.01
Per 1,000 Mortality Rate	28.61	37.58	28.03
Achievement Index	28.18	37.30	28.33

*Significant at 5% level, ** Significant at 1% level

Table 4 P-values of difference in slope between specified years and sexes

A: Males

	2001 vs. 2006	2006 vs. 2011	2001 vs. 2011
0-5	0.782	0.506	0.697
19-39	0.029*	0.015*	0.774
40-59	0.019*	0.014*	0.893
60+	0.016*	0.046*	0.619

B: Females

	2001 vs. 2006	2006 vs. 2011	2001 vs. 2011
0-5	0.174	0.160	0.962
19-39	0.000**	0.001**	0.757
40-59	0.002**	0.009**	0.537
60+	0.820	0.349	0.247

C: Males versus Females

	0-5	*6-18*	*19-39*	*40-59*	*60+*
2001	0.377	0.599	0.028*	0.000**	0.001**
2006	0.966	0.490	0.490	0.003**	0.000**
2011	0.614	0.889	0.212	0.000**	0.000**

*Significant at 5% level, ** Significant at 1% level

Overall Changes in Mortality

Critical in the development of mortality and mortality inequality are the changes that have occurred in the HIV/AIDS and TB epidemics. The changing impact of the two conditions is evident through their overall contribution to South Africa's mortality burden. Namely, whereas in 2000 and 2012, HIV/AIDS and TB were responsible for around 34% of total deaths, they caused more than 45% of all deaths in 2005 (Pillay-van Wyk et al., 2016). The reversal that we observed in overall mortality in 2006 is therefore consistent with the HIV/AIDS and TB developments, as well as with the reported decline in all-cause age-standardized death rates since 2006 by Pillay-van Wyk et al. (2016).

Furthermore, our full population analysis shows the reversal of trends in LE at birth. In line with previous studies (Bradshaw et al., 2015; Gapminder, 2017; Worldbank, 2017), we show a decline in LE at birth over the 2001-2006 period and an increase in LE between 2006 and 2011. However, similar to Bradshaw et al. (2015), we observed differential trends in LE for men and women. Initially, LE at birth decreased relatively more for females than males, possibly because the younger age of HIV infection among females (Bor et al., 2015). Earlier research has identified age-discordant relationships (having a sexual partner who is 5 years or older than the index person) as an important behavioral determinant for this age-gender difference in HIV-infection (Shishana et al., 2014). Namely, 33.6% of all female adolescents aged 15-19 years reported age-disparate relationships, compared to only 4.1% of their male peers (Shisana et al., 2014). Post ART-scale up, the female-male gap in LE increased substantially again. This natural widening of the LE gender gap is partly explained by the fact that prior to the ART-scale up, women were more affected by HIV/AIDS. However, the increase has also been attributed to poorer HIV testing among males (Shisana et al., 2014), men initiating treatment at more advanced stages of HIV (Cornell et al., 2009; Schneider et al., 2012), and females showing better adherence to treatment than males (Kranzer et al., 2010). Better health care seeking behavior among females who experience TB symptoms (Smith et al., 2016), and poorer TB treatment outcomes among males (Ershova et al., 2014) may have also contributed to the aforementioned widening of the gender gap.

Overall Changes in Mortality Inequality

Similar to overall mortality changes, we report that absolute mortality inequality reversed in 2006. This is in line with the HIV/AIDS and TB epidemic developments, as HIV/AIDS and TB have disproportionally affected the on average poorer black African population (Oni & Mayosi, 2016). Also, the observed increase in inequality between 2001 and 2006 suggests that in absolute terms, poorer municipalities were more affected by HIV/AIDS and TB. Encouragingly, the decrease in mortality inequality after 2006 implies that the population living in the poorer and most afflicted municipalities had, in absolute numbers, better access to ART compared to the population living in the on average richer municipalities. Besides the intensified ART programs, improvements in living conditions, poverty headcount, education and social protection, and a more equitable public health system have likely contributed to this decrease in absolute inequality (Ataguba et al., 2015).

Furthermore, our findings imply that relative inequality remained largely constant in the 2001-2011 period. A possible explanation for why relative inequality stayed equal in the 2006-2011 period, despite the overall reductions in mortality and absolute inequality, are the geographical differences in ART coverage. For instance, Adam and Johnson (2009) estimated in 2008 that ART coverage in adults ranged from 72.5% in the Western Cape, a relatively wealthy province, to 25.8% in the Free State. Besides provincial differences in ART coverage, our results thus imply that in relative terms, poorer municipalities did not seem to have better access to ART's.

Overall, taking both the mean and relative inequality of mortality into consideration, our results suggest that the mortality distribution first deteriorated and then improved. As relative inequality stayed constant over time, the observed reversal has largely been driven by changes in mean mortality.

Age-Sex Specific Mortality and Mortality Inequality Changes

In addition to presenting overall changes in South Africa's mortality and LE at birth, we reported differential trends in mortality and in mortality inequality by gender and age. For children under-five, we find for both sexes an almost two-fold drop in mortality between 2006 and 2011, after an earlier increase in the 2001-2006 period. Past trend estimates of under-five mortality in South Africa have shown similar patterns (GHO, 2017; Kerber et al., 2013; UNICEF, 2014). Furthermore, our results suggested that under-five mortality is concentrated among poorer municipalities, although no significant differences were observed in absolute mortality inequality between the different survey years. Focusing on relative inequality, we reported that relative inequality for children under-five, remained stable between 2001 and 2006, but increased after 2006. The effective prevention of mother-to-child transmission of HIV (PMTCT) program and increased immunization levels, both argued to be largely responsible for the reduction in under-five mortality (Mayosi & Benatar, 2014; MDG, 2013), therefore seemed to have benefited the richer municipalities relatively more than the poorer municipalities. This result is in line with Goga et al. (2012), who showed that the percentage of HIV-positive mothers in Gauteng (41%) that received highly active antiretroviral therapy was almost two-fold of the percentage of HIV-positive mothers in the on average poorer Eastern Cape (23%).

As evidence suggests that South Africa's burden of HIV/AIDS is predominantly driven by heterosexual transmission (Fraser-Hurt et al, 2011), adults in the reproductive age group (15-49) are the age group that is most affected by HIV/AIDS (Shisana et al., 2014; Bradshaw et al., 2016; Pillay-van Wyk et al., 2016). Driven by HIV/AIDS, the impact of TB has also hit hardest on the part of the population that is in reproductive age. According to Statistics South Africa (2008), TB was responsible for 20.1% of all deaths in the age group 15-49 in 2006, compared to for example 2.3% in age group 0-14, and 3.2% in the part of the population aged 65+. Unsurprisingly, our presented mortality and absolute inequality reversals are most pronounced in males and females aged 19-39 and 40-59.

For the population aged 19-39, we found a substantial increase in mortality for both sexes between 2001 and 2006, although this increase was relatively larger for females than males. This result is consistent with findings from Bradshaw et al. (2016), who estimated that over the 2000-2005 period, HIV/AIDS mortality for females aged 15-29 years increased to levels double to the levels of male HIV/AIDS mortality. The previously discussed sex difference in age-discordant relationships is argued to be largely responsible for this increased disparity (Shisana et al., 2014). After 2006, our results suggest, however, that mortality for the age group 19-39 decreased starker among females than males. This is probably due to the earlier mentioned gender disparities in health care seeking behavior and treatment adherence. Moreover, in line with the reversed impact of HIV/AIDS and TB since 2006, our results reveal that absolute mortality inequality for the population aged 19-39, substantially increased between 2001 and 2006, and decreased again in the 2006-2011 period. Relative inequality, on the other hand, stayed fairly equal between 2001 and 2006, but increased after 2006. This increase is most likely caused by geographical differences in ART coverage, as well as rising levels of NCD's among people of lower SES. A possible explanation for why relative inequality did not increase during the 2001-2006 period lies in the scope of the HIV/AIDS and TB epidemic. Whereas absolute inequality is sensitive to changes in mean mortality, relatively inequality only changes when the distribution of mortality is affected. Early research showed black Africans over the age of 15 who earned less than 4000 Rand/month had significantly higher HIV prevalence levels than non-black Africans in the same category, or black Africans who earned more than 4000 Rand/month (Shisana et al, 2014). However, the previously described group made up 69% of the population in 2007 (Stats SA, 2007) and had an overall HIV prevalence rate of around 23% (Shisana et al. 2014). Thus, since HIV/AIDS has affected the majority of South Africa's population in a similar way, relative inequality remained largely unaffected by HIV/AIDS.

Despite the fact that women had higher HIV prevalence rates in age group 40-59, we reported worse mortality outcomes for males than females. These gender disparities in mortality are consistent with findings from Bradshaw et al. (2016), who show that for age group 45-59, HIV/AIDS mortality was significantly higher in the 2001-2010 period for males than females. The HIV/AIDS mortality differences are possibly caused by the earlier mentioned gender differences in health care seeking behavior and treatment adherence. Moreover, new pulmonary smear positive TB cases were twice as prevalent in males than females for this age group (WHO, 2017b). The finding that both absolute and relative inequality were higher in this age group among males than females is therefore likely caused by the larger mortality impact of HIV/AIDS and TB on males. However, it could also be the result from variations in health seeking behavior and adherence to treatment by SES within males than females. Thus, further research is needed to understand within socio-economic gender differences in care-seeking behavior and adherence, in order to fully realize the benefits of mass ART and TB treatment provision. Furthermore, we find that both mortality and absolute inequality increased drastically between 2001 and 2006, and decreased again after 2006.

Finally, results for elderly over the age of 60 imply that whereas mortality disparities exist for males aged 60+, mortality was equally distributed across municipalities among their female peers. These findings are in line with results from Bradshaw et al. (2016), who showed that males over the age of 60 are dying from HIV at an increasing rate, while no such increase has been found for females. Again, these gender differences, are probably caused by variation in health seeking behavior and adherence, and possibly because of discordant relationships between older men and younger women.[8]

Limitations

Our study encountered various challenges. First, as mentioned in the 'Study Variables' section, Statistics South Africa published a 10% mortality sample for the 2011 Census, which was sampled differently from the 10% person sample. While the number of deaths was used as our numerator for calculating age-specific mortality rates (person sample), and the number of people surveyed (plus those who died) was used as our denominator (mortality sample), we had to assume that both 10% datasets were randomly drawn. Encouragingly, a comparison in mortality trends and absolute levels by age group, gender and province, between mortality rates obtained from the Census/CS and from adjusted vital registrations showed that, except for age group 60+, the mortality rates used in our study were fairly consistent with the rates from death notifications (see Appendix A). This suggests that, overall, our mortality rates are an accurate representation of deaths which occurred in South Africa.

Second, since mortality questions were not asked to the population living in institutions this group was excluded from our analysis. The omission of institutions may have led to biased mortality and mortality inequality estimates, while the White population, for example, has a higher proportion of people living in institutions such as old age homes (Dorrington, Moultrie & Timæus, 2004). However, the bias is probably limited, due to the relatively small proportion of people living in institutions. Yu (2009) for instance estimates that in 2007 only 1.4% of the population was living in institutions.

Third, all three surveys used for this study had a high proportion of unspecified individual incomes (2001: 15.6%, 2006: 5.48%, 2011: 13.95%). Evidence suggests that particularly White people, as well as people living in the Western Cape and Gauteng, are more likely to have missing income values than other population groups and provinces (Ardington et al., 2006). While this is on average the richer part of population, ignoring missing values may have downwardly biased our income estimates. For the 2001 data, however, this issue was averted by using the imputed 2001 version. In addition, despite the

[8] While large differences in absolute mortality and trends where observed between mortality estimates obtained from death notifications and Census/CS deaths for people aged 60+, one should be careful interpreting the 60+ results.

imputations of 2001, all surveys consisted of a high proportion of zero household incomes (2001: 12.2%, 2006: 7.3%, 2011: 7.9%). However, as omitting them would lead to biased results (Yu, 2009), we decided to include them in the analysis anyway.

Finally, the results presented are the first to show trends in mortality inequality by income for different demographic groups for South Africa over the 2001-2011 period. However, our analysis is unable to fully identify the drivers of these changes. There is thus need for further research to decompose the inequality effect. Furthermore, our research is restricted to the 2000-2011 period. Thus, the impact of influential policy changes and developments which occurred after 2011 are not captured. For example, the number of HIV infected people in South Africa receiving ART almost doubled between 2011 and 2014 (SANAC, 2016). In addition, the CD4 threshold for ART initiation initially increased from 350 cells/µl to 500 cells/µl in 2014, and South Africa has formally adopted the 'Test and Treat' policy since 2016, which implies that all HIV positive, children, adolescents and adults are offered ART treatment regardless of CD4 count (NDOH, 2016). The resulting increases in ART provision are most likely to further reduce disparities in health. Another example is the introduction of a new drug regime called the 'Fixed Dose Combinates' in 2013 (SANAC, 2016). This regime reduces the drug intake from three times a day to just one tablet a day, which is known to improve treatment uptake and adherence. Better adherence has most likely reduced mortality inequality, and might have resulted in reduced disparities between males and females.

5 Conclusion

This study demonstrates that South Africa's post-apartheid dedication to improve health outcomes and reducing its inherited health disparities has translated into mixed successes. South Africa has managed to reverse mortality and absolute mortality inequality since 2006, but relative inequality remained high during the 2001-2011 period. On the whole, by taking both the mean and relative distribution of mortality into consideration, our results suggest that South Africa achieved a similar mortality outcome distribution in 2011 as in 2001. Large disparities in mortality by SES thus continue to exist.

By identifying the age-sex groups which require most attention, this study provides actionable information. Traditionally, gender-targeted programming has sought to improve health outcomes for females. However, our results suggest that considerable gains could be made in reducing gender mortality disparities by implementing male-sensitive programs. The South African government should focus particularly on designing effective interventions that increase the uptake of HIV and TB services among males, as well as approaches to healthcare delivery which improve their treatment adherence. Furthermore, the observed reversal of adult absolute mortality inequality suggests that HIV/AIDS and TB treatment programs have successfully reached the on average poorer municipalities. The increase in relative inequality for age groups 0-5 and 19-39 after 2006, however, implies that people in richer municipalities have benefited relatively more from the immunization, PMTCT, ART and TB scale-up programs. To reduce disparities in health, South Africa must therefore identify and renew its focus on the geographical areas which have been most afflicted HIV/AIDS and TB. Particularly in those areas, improved access to a full range of social services, awareness, and better health care seeking and sexual behavior could lead to major improvements in the distribution of health.

5 References

Adam, M. A., & Johnson, L. F. (2009). Estimation of adult antiretroviral treatment coverage in South Africa: original article. *South African Medical Journal*, 99(9), 661-667.

Ardington, C., Lam, D., Leibbrandt, M., & Welch, M. (2006). The sensitivity to key data imputations of recent estimates of income poverty and inequality in South Africa. *Economic Modelling*, *23*(5), 822-835.

Ataguba, J. E., Akazili, J., & McIntyre, D. (2011). Socioeconomic-related health inequality in South Africa: evidence from General Household Surveys. *International journal for equity in health*, *10*(1), 48.

Ataguba, J. E. O., Day, C., & McIntyre, D. (2015). Explaining the role of the social determinants of health on health inequality in South Africa. *Global health action*, *8*.

Barnes, H., Gutierrez-Romero, R., & Noble, M. (2006). *Multiple Imputation of Missing Data in the 2001 South African Census.* Oxford: Centre for the Analysis of South African Social Policy

Benatar, S. (2013). The challenges of health disparities in South Africa. *SAMJ: South African Medical Journal*, *103*(3), 154-155.

Blacker, J. (2004). The impact of AIDS on adult mortality: evidence from national and regional statistics. *Aids*, *18*, S19-S26

Bor, J., Rosen, S., Chimbindi, N., Haber, N., Herbst, K., Mutevedzi, T., ... & Bärnighausen, T. (2015). Mass HIV treatment and sex disparities in life expectancy: demographic surveillance in rural South Africa. *PLoS Med*, *12*(11), e1001905.

Bouman, A., Heineman, M. J., & Faas, M. M. (2005). Sex hormones and the immune response in humans. Human reproduction update, 11(4), 411-423.

Bradshaw, D., Groenewald, P., Laubscher, R., Nannan, N., Nojilana, B., Norman, R., ... & Dorrington, R. (2003). Initial burden of disease estimates for South Africa, 2000. *South African Medical Journal*, *93*(9), 682-688.

Bradshaw, D., Dorrington, R. E., & Laubscher, R. (2015). Rapid mortality surveillance report 2014. *Cape Town: South African Medical Research Council*.

Bradshaw, D., Msemburi, W., Dorrington, R., Pillay-van Wyk, V., Laubscher, R., Groenewald, P., & South African National Burden of Disease Study team. (2016). HIV/AIDS in South Africa: how many people died from the disease between 1997 and 2010? *Aids*, *30*(5), 771-778.

Burger, R., Bredenkamp, C., Grobler, C., & van der Berg, S. (2012). Have public health spending and access in South Africa become more equitable since the end of apartheid?. *Development Southern Africa*, *29*(5), 681-703.

Case, A., & Deaton, A. (1998). Large cash transfers to the elderly in South Africa. *The Economic Journal*, *108*(450), 1330-1361.

Charasse-Pouélé, C., & Fournier, M. (2006). Health disparities between racial groups in South Africa: a decomposition analysis. *Social Science & Medicine*, *62*(11), 2897-2914.

Chetty, R., Stepner, M., Abraham, S., Lin, S., Scuderi, B., Turner, N., ... & Cutler, D. (2016). The association between income and life expectancy in the United States, 2001-2014. *Jama*, 315(16), 1750-1766.

Chiang, C. L. (1984). Life table and its applications. In *Life table and its applications*. Robert E. Krieger Publishing.

Churchyard, G. J., Mametja, L. D., Mvusi, L., Ndjeka, N., Hesseling, A. C., Reid, A., ... & Pillay, Y. (2014). Tuberculosis control in South Africa: Successes, challenges and recommendations. *SAMJ: South African Medical Journal*, *104*(3), 234-248.

Cockburn, N., Steven, D., Lecuona, K., Joubert, F., Rogers, G., Cook, C., & Polack, S. (2012). Prevalence, causes and socio-economic determinants of vision loss in Cape Town, South Africa. *PloS one*, *7*(2), e30718.

Coovadia, H., Jewkes, R., Barron, P., Sanders, D., & McIntyre, D. (2009). The health and health system of South Africa: historical roots of current public health challenges. *The Lancet*, *374*(9692), 817-834.

Cornell, M., Myer, L., Kaplan, R., Bekker, L. G., & Wood, R. (2009). The impact of gender and income on survival and retention in a South African antiretroviral therapy programme. *Tropical Medicine & International Health*, *14*(7), 722-731.

Currie, J., & Schwandt, H. (2016). Mortality inequality: the good news from a county-level approach. *The Journal of Economic Perspectives*, *30*(2), 29-52.

Deaton, A. S., & Paxson, C. (2001). Mortality, education, income, and inequality among American cohorts. *Themes in the Economics of Aging* (pp. 129-170). University of Chicago Press.

Deaton, A. (2002). Policy implications of the gradient of health and wealth. *Health affairs*, *21*(2), 13-30.

Delobelle, P. (2013). The health system in South Africa: Historical perspectives and current challenges. *In South Africa in focus: Economic, political and social issues,* 159–96.

DOBE (2014). *Education for All 2014 Country Progress Report.* Pretoria: Republic of South Africa. Pretoria: Department of Basic Education

Doolan, K., Ehrlich, R., & Myer, L. (2007). Experience of violence and socioeconomic position in South Africa: a national study*. Plos One*, 2(12), e1290.

Dorrington, R. (2013). Alternative South African mid-year estimates, 2013. *Cape Town: University of Cape Town*.

DPME. (2014). *Development Indicators 2014.* Pretoria: Department: Planning, Monitoring and Evalution

Ershova, J. V., Podewils, L. J., Bronner, L. E., Stockwell, H. G., Dlamini, S., & Mametja, L. D. (2014). Evaluation of adherence to national treatment guidelines among tuberculosis patients in three provinces of South Africa. *South African Medical Journal*, 104(5).

Fraser-Hurt, N., Zuma, K., Njuho, P., Chikwava, F., Slaymaker, E., Hosegood, V., & Gorgens, M. (2011). The HIV epidemic in South Africa: what do we know and how has it changed?

Goga, A., Dinh, T. H., & Jackson, D. (2012). *Evaluation of the effectiveness of the national prevention of mother-to-child transmission (PMTCT) progra on infant HIV measured at six weeks postpartum in South Africa.* South African Medical Research Council, National Department of Health South Africa and PEPFAR/US Centers for Disease Control & Prevention.

Goudge, J., Gilson, L., Russell, S., Gumede, T., & Mills, A. (2009). The household costs of health care in rural South Africa with free public primary care and hospital exemptions for the poor. *Tropical medicine & international health*, *14*(4), 458-467.

Gouws, E., Karim, Q. A. (2010). HIV infection in South Africa: the evolving epidemic. *HIV/AIDS in South Africa*, 48-66.

Harling, G., Ehrlich, R., & Myer, L. (2008). The social epidemiology of tuberculosis in South Africa: a multilevel analysis*. Social science & medicine*, 66(2), 492-505.

Harris, B., Goudge, J., Ataguba, J. E., McIntyre, D., Nxumalo, N., Jikwana, S., & Chersich, M. (2011). Inequities in access to health care in South Africa. *Journal of public health policy*, *32*(1), S102-S123.

Harrison, D. (2009). An overview of health and health care in South Africa 1994–2010: Priorities, progress and prospects for new gains. *Washington, DC: Henry J Kaiser Family Foundation*.

Idler, E. L., & Benyamini, Y. (1997). Self-rated health and mortality: a review of twenty-seven community studies. *Journal of health and social behavior*, 21-37.

Idler, E. L., Russell, L. B., & Davis, D. (2000). Survival, functional limitations, and self-rated health in the NHANES I epidemiologic follow-up study, 1992. *American journal of epidemiology*, *152*(9), 874-883.

Johnson, L. F. (2012). Access to antiretroviral treatment in South Africa, 2004-2011: original article. *Southern African Journal of HIV Medicine*, *13*(1), 22-27

Johson, L. F. (2014). THEMBISA version 1.0: A model for evaluating the impact of HIV/AIDS in South Africa. *Centre for Infectious Disease Epidemiology and Research Working Paper*

Johnson, L. F., Rehle, T. M., Jooste, S., & Bekker, L. G. (2015). Rates of HIV testing and diagnosis in South Africa: successes and challenges. *AIDS*, *29*(11), 1401-1409.

Karim, S. S. A., Churchyard, G. J., Karim, Q. A., & Lawn, S. D. (2009). HIV infection and tuberculosis in South Africa: an urgent need to escalate the public health response. *the Lancet*, *374*(9693), 921-933.

Kranzer, K., Lewis, J. J., Ford, N., Zeinecker, J., Orrell, C., Lawn, S. D., ... & Wood, R. (2010). Treatment interruption in a primary care antiretroviral therapy programme in South Africa: cohort analysis of trends and risk factors. *Journal of acquired immune deficiency syndromes (1999)*, *55*(3), e17.

Kerber, K. J., Lawn, J. E., Johnson, L. F., Mahy, M., Dorrington, R. E., Phillips, H., ... & Walker, N. P. (2013). South African child deaths 1990–2011: have HIV services reversed the trend enough to meet Millennium Development Goal 4?. Aids, 27(16), 2637-2648.

Larson, E., O'Bra, H., Brown, J. W., Mbengashe, T., & Klausner, J. D. (2012). Supporting the massive scale-up of antiretroviral therapy: the evolution of PEPFAR-supported treatment facilities in South Africa, 2005-2009. *BMC Public Health*, 12(1), 173.

Leibbrandt, M., Poswell, L., Naidoo, P., Welch, M., & Woolard, I. (2006). Measuring recent changes in South African inequality and poverty using 1996 and 2001 census data. *Poverty and policy in post-apartheid South Africa*, 95-142.

Leibbrandt, M., Woolard, I., Finn, A., & Argent, J. (2010). Trends in South African income distribution and poverty since the fall of apartheid.

Mayosi, B. M., Flisher, A. J., Lalloo, U. G., Sitas, F., Tollman, S. M., & Bradshaw, D. (2009). The burden of non-communicable diseases in South Africa. *The Lancet*, *374*(9693), 934-947.

Mayosi, B. M., & Benatar, S. R. (2014). *New England Journal of Medicine*, *371*(14), 1344-1353.

McIntyre, D., & Gilson, L. (2001). Social Africa: addressing the legacy of apartheid. *Challenging inequalities in health: From ethics to action*.

Mcintyre, D., Thiede, M., Nkosi, M., Mutyambizi, V., Castillo-riquelme, M., Gilson, L., ... & Goudge, J. (2007). SHIELD work package 1 report: a critical analysis of the current South African Health System.

McLaren, Z. M., Ardington, C., & Leibbrandt, M. (2014). Distance decay and persistent health care disparities in South Africa. *BMC health services research*, *14*(1), 541.

Mills, A., Ataguba, J. E., Akazili, J., Borghi, J., Garshong, B., Makawia, S., ... & McIntyre, D. (2012). Equity in financing and use of health care in Ghana, South Africa, and Tanzania: implications for paths to universal coverage. *The Lancet*, *380*(9837), 126-133.

Myer, L., Stein, D. J., Grimsrud, A., Seedat, S., & Williams, D. R. (2008). Social determinants of psychological distress in a nationally-representative sample of South African adults. *Social science & medicine*, 66(8), 1828-1840

Nannan, N., Dorrington, R., Laubscher, R., Zinyakatira, N., Prinsloo, M., Darikwa, T. B., ... & Bradshaw, D. (2012). Under-5 mortality statistics in South Africa: Shedding some light on the trends and causes 1997–2007. *Cape Town: South African Medical Research Council*

NDOH. (2004). *No. 61 of 2003: National Health Act, 2003.* Cape Town: Government Gazette

NDOH. (2007). *Tuberculosis Strategic Plan for South-Africa, 2007-2011* Pretoria: National Department of Health.

NDOH. (2012). *National Strategic Plan on HIV, STIs and TB, 2012-2016* Pretoria: National Department of Health.

NDOH. (2013). *The 2013 National Antenatal Sentinel HIV Prevalence Survey South Africa.* Pretoria: National Department of Health.

NDOH (2016, March 28). *Implementation of the universal test and treat strategy for HIV positive and differentiated care for stable patients.* Retrieved from The Southern African HIV Clinicians Society: http://www.sahivsoc.org/Files/22%208%2016%20Circular%20UTT%20%20%20Decongestion%20CCMT%20Directorate%20(2).pdf

Nkonki, L. L., Chopra, M., Doherty, T. M., Jackson, D., & Robberstad, B. (2011). Explaining household socio-economic related child health inequalities using multiple methods in three diverse settings in South Africa. *International journal for equity in health*, *10*(1), 13.

Nojilana, B., Bradshaw, D., Pillay-van Wyk, V., Msemburi, W., Laubscher, R., Somdyala, N. I., ... & Dorrington, R. E. (2016). Emerging trends in non-communicable disease mortality in South Africa, 1997-2010. *SAMJ: South African Medical Journal*, 106(5), 477-484.

Oni, T., & Mayosi, B. M. (2016). Mortality trends in South Africa: progress in the shadow of HIV/AIDS and apartheid. *The Lancet Global Health*, *4*(9), e588-e589.

Posel, D., Rogan, M. (2014) Measured as poor versus feeling poor. Comparing objective and subjective poverty rates in South Africa. *UNU-WIDER, Working Paper 2014/133*

Pillay-van Wyk, V., Msemburi, W., Laubscher, R., Dorrington, R. E., Groenewald, P., Glass, T., ... & Nannan, N. (2016). Mortality trends and differentials in South Africa from 1997 to 2012: second National Burden of Disease Study. *The Lancet Global Health*, *4*(9), e642-e653.

Regidor, E. (2004). Measures of health inequalities: part 2. *Journal of epidemiology and community health*, *58*(11), 900

Rossouw, L. (2015). Do poor South Africans underestimate their health needs? *UNU-WIDER, Working Paper 2015/027,* 22.

SANAC (2016). *Enhanced Progress Report of the South African National Strategic plan on HIV, STIs and TB: 2012-2016.* Pretoria: South African National Aids Council.

Schneider, H., Govender, V., Harris, B., Cleary, S., Moshabela, M., & Birch, S. (2012). Gender differences in experiences of ART services in South Africa: a mixed methods study. *Tropical Medicine & International Health*, *17*(7), 820-826.

Section 27. (2013). *Dead and Dying in the Eastern Cape. An investigation into the collapse of a health system.* Treatment Action Campaign and Section27 Catalysts for Social Justice

Shisana, O., Rehle, T., Simbayi, L. C., Zuma, K., Jooste, S., Zungu, N., ... & Onoya, D. (2014). South African national HIV prevalence, incidence and behaviour survey, 2012.

Shorrocks, A. F. (1983). Ranking income distributions. *Economica*, *50*(197), 3-17

Simelela, N. P., and W. D. F. Venter. "A brief history of South Africa's response to AIDS." *SAMJ: South African Medical Journal* 104, no. 3 (2014): 249-251.

Smith, A., Burger, R., Claassens, M., Ayles, H., Godfrey-Faussett, P., & Beyers, N. (2016). Health care workers' gender bias in testing could contribute to missed tuberculosis among women in South Africa. The international journal of tuberculosis and lung disease, 20(3), 350-356.

Stats SA (2001). *Census 2001 10% Sample.* Pretoria: Statistics South Africa

Stats SA (2005). *Mortality and causes of death in South Africa, 1997-2003. Findings from death notification. Statistical Release P0309.3.* Pretoria: Statistics South Africa

Stats SA (2007). *Community Survey, 2007 (revised Version)*. Pretoria: Statistics South Africa

Stats SA (2008). *Mortality and causes of death in South Africa, 2006. Findings from death notification. Statistical Release P0309.3.* Pretoria: Statistics South Africa

Stats SA (2011). *Census 2011 10% Sample Metadata.* Pretoria: Statistics South Africa.

Stats SA (2013). *Millennium Development Goals Country Report 2013.* Pretoria: Statistics South Africa.

Stats SA (2014). *Mortality and causes of death in South Africa, 2011. Findings from death notification. Statistical Release P0309.3.* Pretoria: Statistics South Africa

Stats SA (2015a). *General Household Survey 2015. Statistical release P0318.* Pretoria: Statistics South Africa.

Stats SA (2015b). *Millennium Development Goals 5: Improve maternal health 2015.* Pretoria: Statistics South Africa.

Stats SA (2015c). *Mid-year population estimates 2014. Statistical release P0302*. Pretoria: Statistics South Africa.

Stats SA (2016). *Water and Sanitation In-depth analysis of the General Household Survey 2002–2015 and Community Survey 2016 data. GHS Series Volume VIII.* Pretoria: Statistics South Africa.

Stats SA (2017a). *Community Survey 2016. Statistical Release P0301.* Pretoria: Statistics South Africa

Stats SA (2017b, February 7). *CPI History: 1960 onwards.* Retrieved from Stats SA: http://www.statssa.gov.za/?page_id=1854&PPN=P0141

Terreblanche, S. (2002). *A History of Inequality in South Africa 1652-2002.* University Of KwaZulu Natal Press.

Timaeus, I. (1991). Estimation of adult mortality from orphan hood before and since marriage. *Population Studies*, *45*(3), 455-472.

UNAIDS. (2016). *Preventive Gap Report 2016.* Geneva: UNAIDS

UNICEF. (2014). *Levels & Trends in Child Mortality. Report 2014.* New York: United Nations Children's Funds

UNDP. (2014). *Human Development Report 2014. Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience.* New York :United Nations Development Programme

Van Doorslaer, E., & Gerdtham, U. G. (2003). Does inequality in self-assessed health predict inequality in survival by income? Evidence from Swedish data. *Social science & medicine*, *57*(9), 1621-1629.

Wabiri, N., Chersich, M., Zuma, K., Blaauw, D., Goudge, J., & Dwane, N. (2013). Equity in Maternal health in South Africa: analysis of health service access and health status in a national household survey. *PLoS One*, *8*(9), e73864.

Wabiri, N., Chersich, M., Shisana, O., Blaauw, D., Rees, H., & Dwane, N. (2016). Growing inequities in maternal health in South Africa: a comparison of serial national household surveys. *BMC pregnancy and childbirth*, *16*(1), 256

Wagstaff, A., Paci, P., & Van Doorslaer, E. (1991). On the measurement of inequalities in health. *Social science & medicine*, *33*(5), 545-557.

Wagstaff, A. (2002). Inequality aversion, health inequalities and health achievement. *Journal of health economics*, *21*(4), 627-641

Wagstaff, A., O'Donnell, O., Van Doorslaer, E., & Lindelow, M. (2007). *Analyzing health equity using household survey data: a guide to techniques and their implementation*. World Bank Publications.

Waldron, I. (1998). Sex differences in infant and early childhood mortality: Major causes of death and possible biological causes. NA.

WHO. (2013). *Handbook on health inequality monitoring: with a special focus on low-and middle-income countries.* Geneva: World Health Organization

WHO. (2016). *Global Tuberculosis Report 2016.* Geneva: World Health Organization.

WHO. (2017a, February 16). Global Health Observatory South Africa statistics summary (2002-persent). Retrieved from WHO: http://apps.who.int/gho/data/node.country.country-ZAF

WHO. (2017b, February 16). Tuberculosis Country Data. Retrieved from WHO: http://www.who.int/tb/country/data/download/en/

Wolfson, M., & Rowe, G. (2001). On measuring inequalities in health. *Bulletin of the World Health Organization*, *79*(6), 553-560.

World Bank. (2017, February 10). Retrieved from GINI index (World Bank estimate): http://data.worldbank.org/indicator/SI.POV.GINI

Yu, D. (2009). *The comparability of Census 1996, Census 2001 and Community Survey 2007* (No. 21/2009).

Zere, E., & McIntyre, D. (2003). Inequities in under-five child malnutrition in South Africa. *International journal for equity in health*, *2*(1), 7.

Appendix

A: Differences in Census/CS mortality rates vs. Death Notification mortality rates

Table A1 Completeness ratios used

	Age 0-4			Age 5-19			Age 20-39, 40-59, 60+		
Province/ Year	2001	2006	2011	2001	2006	2011	2001	2006	2011
Western Cape	85.0	68.5	87.5	87.6	87.6	90.2	108.2	97.1	100.4
Eastern Cape	31.7	40.3	49.5	70.4	84.4	83.7	73.8	90.7	87.4
Northern Cape	76.0	77.2	112.6	72.8	80.1	95.7	78.5	82.1	111.4
Free State	73.3	108.0	104.2	81.1	89.9	93.9	95.1	101.7	107.7
KwaZulu-Natal	44.1	58.6	53.1	73.6	80.1	81.7	80.2	82.1	83.4
North West	73.3	122.3	95.6	82.1	93.4	86.1	97.1	108.8	92.1
Gauteng	85.7	106.5	94.2	86.2	86.0	87.5	105.3	94.0	95.0
Mpumalanga	43.8	69.3	68.8	71.5	79.6	84.3	76.0	81.2	88.6
Limpopo	40.5	78.2	92.7	73.6	94.1	93.7	80.1	110.1	107.3

Sources: Pillay-Van Wyk (2014). Due to absence of 2011 estimates, we applied 2010 estimates for the year 2011.

Data on Deaths Notifications, also called Administrative Deaths (AD) or Vital Registrations are annually released by Stats SA. However, as mentioned in the 'Methods and Data' section, death notifications at small geographical levels are not publicly available. As a result, it is only possible to examine differences between Census/CS mortality rates and administrative mortality rates at the province level (South Africa's geographical frame consist of 9 provinces). While South Africa's vital registrations are not complete, as in most other low-middle income countries (Nannan et al.,2014), we had to adjust deaths by completeness ratios. The adjustments rates used in our analysis are derived from Pillay-van Wyk et al. (2014), and presented ins Table A1.

Next, age-sex-province specific Census/CS mortality rates are calculated by dividing the number of deaths within a province-sex-age group that occurred in the 12 months before the survey by the number of deaths plus population surveyed within this specified group. To obtain mortality rates from death notifications, we used the traditional formula:

$$Mortality\ Rate(xit) = \frac{Number\ of\ adjusted\ Deaths\ (xit)}{\frac{1}{2}x(Population\ size\ (xi)\ at\ beginning\ year\ t + population\ size(xi)\ at\ end\ year\ t)}$$

where *x* represents the age group, *i* gender, and *t* year. The population size estimates are derived from Dorrington's (12) alternative mid-year population estimates.

Table A2 Average absolute province differences in (per 1,000) 1-year mortality estimates by age group, gender and year between Census/CS mortality estimates and death notification estimates.

	Male			Female			
	2001	2006	2011	2001	2006	2011	Ave.
0-4	6.15	4.12	3.51	6.48	2.34	2.99	4,27
5-19	0.22	0.42	0.12	0.43	0.79	0.15	0,36
20-39	1.13	4.79	1.31	0.99	4.15	0.72	2,18
40-59	2.63	5.90	3.18	2.38	2.06	2.08	3,04
60+	5.24	10.05	15.24	11.66	3.79	15.12	10,18
Ave.	3,07	5,06	4,67	4,39	2,63	4,21	

Table A3 Percentage of provinces in which same the changes occurred for AD and survey mortality estimates by age group, gender and year.

	Male				Female			
AD	2001-2006	2006-2011	2001-2011	Ave.	2001-2006	2006-2011	2001-2011	Ave.
0-4	44%	100%	100%	81%	44%	100%	89%	78%
5-19	89%	89%	44%	74%	89%	100%	22%	70%
20-39	100%	100%	78%	93%	89%	89%	56%	78%
40-59	100%	89%	22%	70%	89%	89%	67%	81%
60+	78%	22%	44%	48%	56%	11%	56%	41%
Ave.*	82%	80%	58%		73%	78%	58%	

*Ave.: Average

In Table A2, the average absolute differences in one-year mortality estimates between Census/CS and vital registrations are given. To be specific, this is the average province difference in mortality estimates between Census/CS and AD for certain age and gender groups. Hence, the results suggest that the absolute differences was largest for age group 60+, followed by a relatively large difference in under-four mortality (mostly caused by differences in 2001 estimates). For all other age groups, the mortality estimates derived from the two different data sources appears to be quite similar.

Furthermore, since in our main analysis we are observing trends in mortality, it is important to examine whether similar changes would have occurred if we had used AD's estimates instead of Census/CS estimates. Therefore, we examined by gender, age and province if there was a similarity between the two data sources in the direction (increase or decrease) of mortality. The results are presented in Table A3. For example, between 2001 and 2006, we observed in 82% of the provinces of all male age groups a mortality change in the same direction. The differences in change for age group 60+ are more ambiguous, as are differences between the year 2001 and 2011.

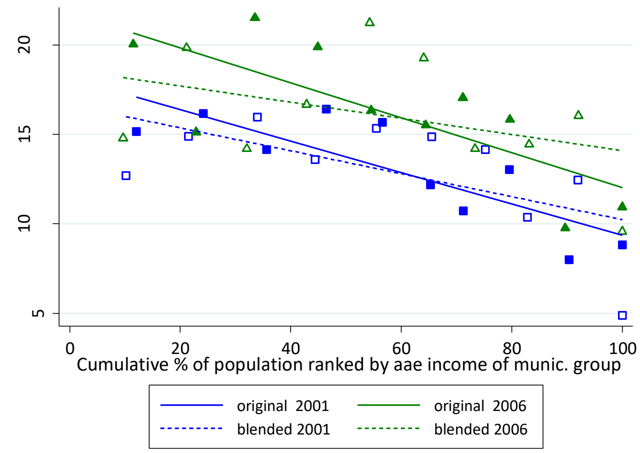
B: Comparison of mortality slopes between 'Original Approach' and 'Blended Approach'

As described in the 'Methods and Data' section, in the blended approach, each of large municipalities are subdivided into five smaller groups, which are then distributed over the ten municipality groups. As a result, poor household *x* in Cape Town now belongs to the poorest municipality group. If we had applied the original approach, this same poor household *x* would belong to one of the richest municipality groups. Thus, given the piecewise linear approximation and improved accuracy of ranking by income, we would expect that the blended approach results in higher degrees of absolute inequality. Hence, in graphs B1-B4, we would expect the slope of the blended version to be steeper than the original version.

However, our findings suggest that except for age group 60+, the blended version resulted in lower absolute mortality inequality, as indicated by the flatter lines in the graphs below. Three possible explanations exist for this surprising finding. One, it is plausible that not income, but the area you live in determines your health status. This is consistent with Chetty's et al. (2016) findings, who show that in the US, similar low-income individuals tend to live longer in cities with highly educated populations, high incomes, and where government expenditures are high. Second, all surveys consisted of a high proportion of zero household incomes. Thus, it is possible that the household with zero income are in reality not that poor, and that placing them into the poorest municipality groups results in incorrect findings. Third, it may be that the more aggregate analysis (original approach) is closer to the truth, due to higher levels of noise in the data.

Table B1: One-year mortality for population aged 0-5 across groups of municipalities ranked by income

Male 0-5



Female 0-5

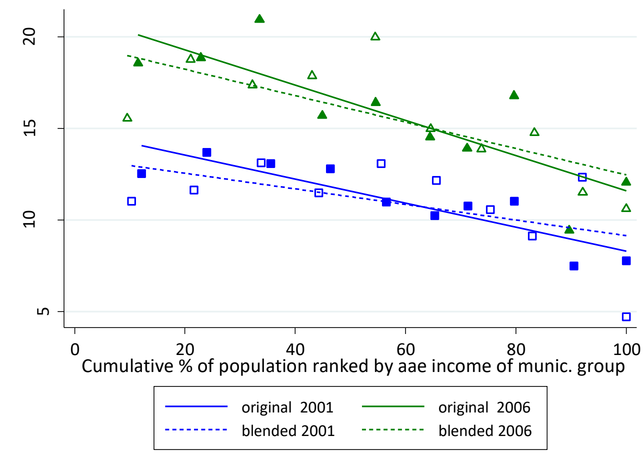
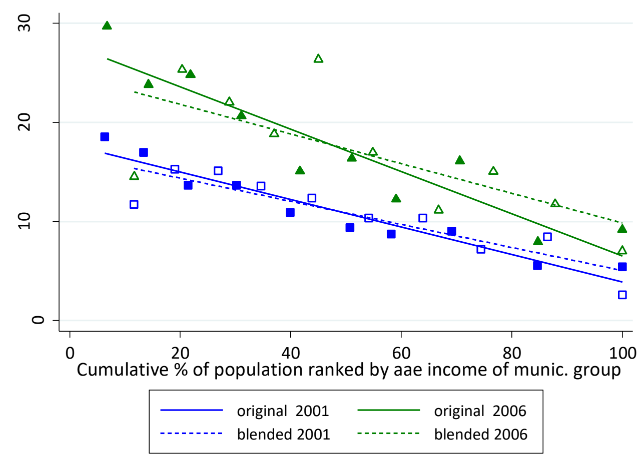


Table B2: One-year mortality for population aged 19-39 across groups of municipalities ranked by income

Male 19-39



Female 19-39

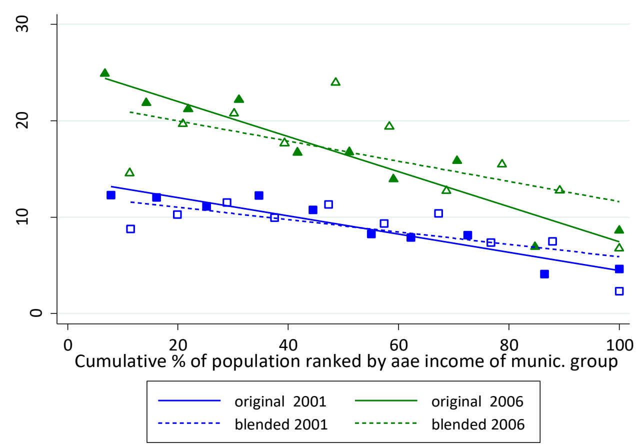
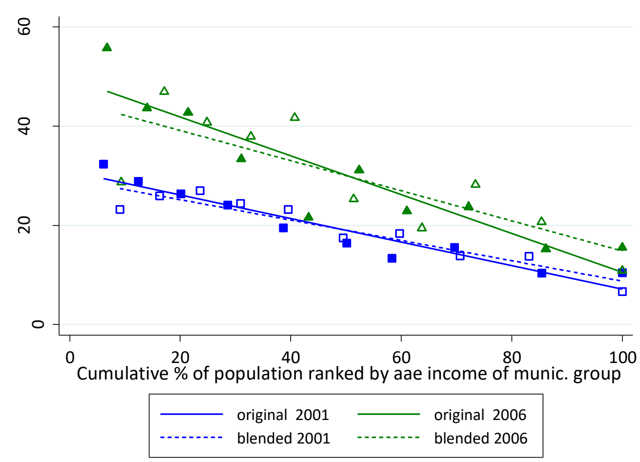


Table B3: One-year mortality for population aged 40-59 across groups of municipalities ranked by income

Male 40-59



Female 40-59

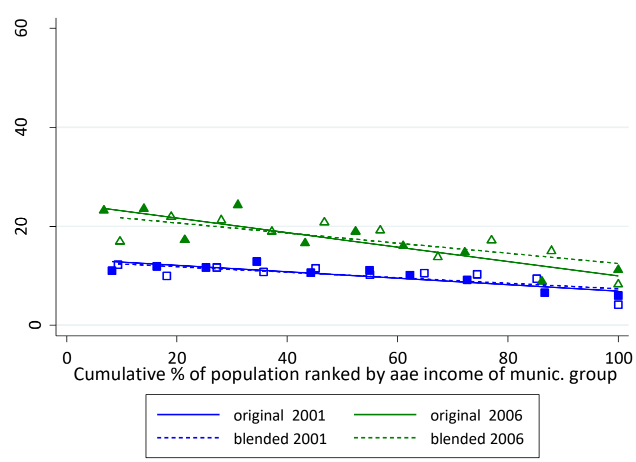
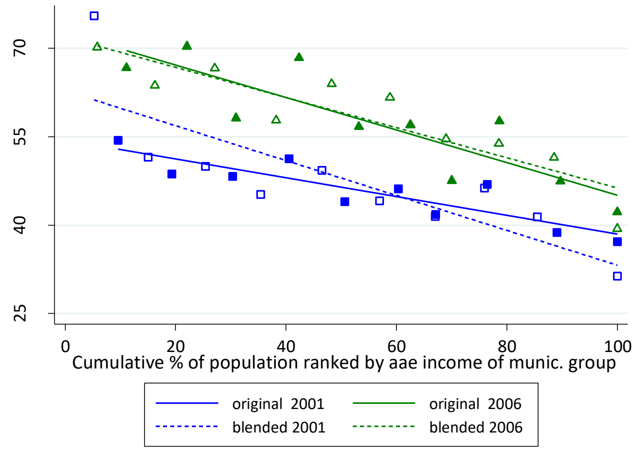
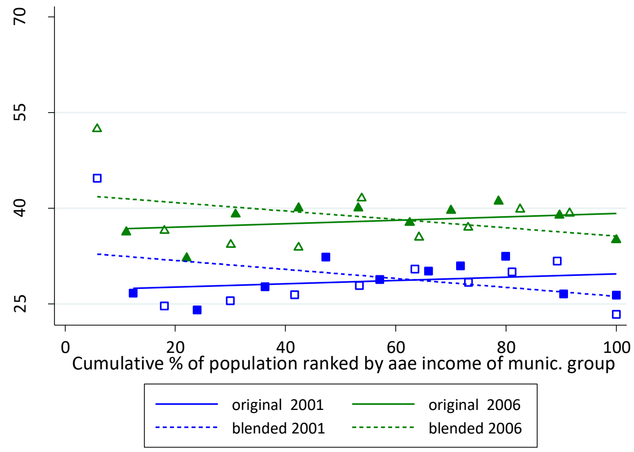


Table B4: One-year mortality for population aged 19-39 across groups of municipalities ranked by income

Male 60+



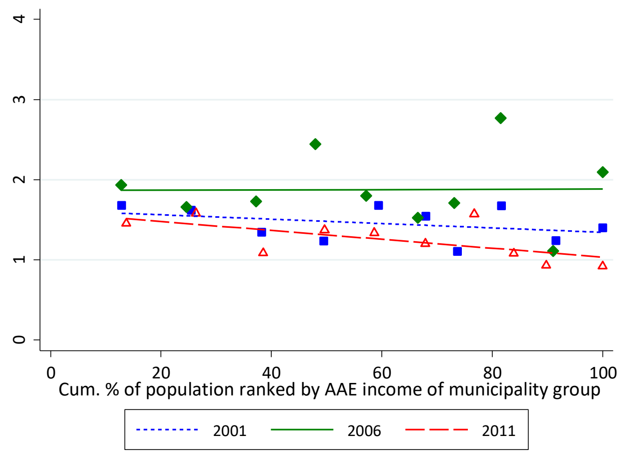
Female 60+



C: Age-sex specific one-year mortality for age group 6-18 (Original Approach)

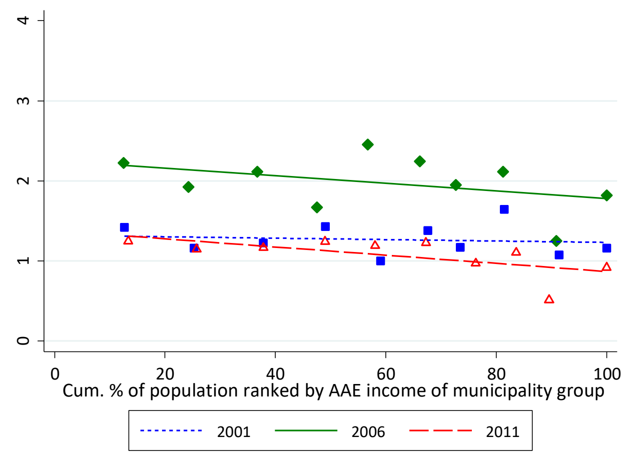
Table C1: One-year mortality for population aged 6-18 across groups of municipalities ranked by income

Male 6-18



Measure	2001	2006	2011
Slope Index	0.00	0.00	-0.01
Concentration Index	-0.03	0.00	-0.06
Per 1,000 Mortality Rate	1.45	1.88	1.25
Achievement Index	1.50	1.88	1.34

Female 6-18



Measure	2001	2006	2011
Slope Index	0.00	0.00	-0.01
Concentration Index	-0.01	-0.04	-0.07
Per 1,000 Mortality Rate	1.27	1.98	1.08
Achievement Index	1.28	2.05	1.16