EVALUATING THE INTEGRITY OF OFFICIALLY PUBLISHED NUMBERS OF DEATHS FROM THE VITAL REGISTRATION SYSTEM AND ESTIMATING MORTALITY LEVELS AT NATIONAL AND PROVINCIAL LEVELS IN SOUTH AFRICA, 2017

BY

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ABSTRACT

Mortality indicators are quantitative measures of mortality levels, and sometimes used for comparing the health status of different populations. A vital registration system is one of the sources of data for computing such measures. However, the trend in the officially published absolute numbers of deaths in South Africa post 2006 is odd given that South Africa's population is increasing in absolute terms and gradually ageing. This raises doubt about the integrity of the officially published figures. The overall aim of this study, therefore, was to evaluate the integrity of the officially published numbers of deaths from South Africa's vital registration system. The study provided two new concepts – uninduced and induced underreporting – in the process of the evaluation. The analysis included fitting the Growth Balance method to the data. The results suggest that at least about 135,659 deaths that were probably reported by the deceaseds' relatives in 2017 were not included in the officially published figures at national level for the year 2017. In the light of the results policy makers and other users of mortality figures for planning and research need to consider that the true number of deaths each year in South Africa post 2006, may be larger by a factor of at least 1.3 than the officially published numbers of deaths for each year.

INTRODUCTION

Background

Mortality pertains to death. Although the probability of death for any individual is 1.0 (i.e., every person will die at some point), at a population level, the level of mortality is one of the indicators of the health status or wellbeing or level of development of that population. Several indicators such as infant mortality, under five mortality, life expectancy at birth have been used to portray and compare the health status or level of development of different populations. For example, Reidpath and Allotey (2003) have noted that infant mortality rate remains an important indicator of heath for whole populations, reflecting the intuition that structural factors affecting the health of entire populations have impact on the mortality rate of infants. According to Sen (2001), mortality information can throw light on the nature of social inequalities.

From a demographic perspective, mortality is one of the drivers of population change or population growth, the other drivers being fertility and migration. The relationship between mortality and population change is described in the demographic balancing equation expressed as:

$P(t) = P(0) + B[0,t] – D[0,t] + I[0,t] – O[0,t]$ (Preston et al. 2001)

Where:

P(t) = the number of persons alive in the population at time t,
P(0) = the number of persons alive in the population at time 0,
B[0,t] = the number of births in the population between time 0 and time t,
D[0,t] = the number of deaths in the population between time 0 and time t,
I[0,t] = the number of in-migrants in the population between time 0 and time t,
O[0,t] = the number of out-migrants in the population between time 0 and time t,

Vital registration systems constitute one of the traditional sources of mortality information.

Problem Statement

The trend in the officially published absolute numbers of deaths from the vital registration system in South Africa suggests that the numbers increased each year up to the period 2006 and thereafter began a decline each year. This pattern is odd given that South Africa's population is increasing in absolute terms as well as gradually ageing. It is counter intuitive to have decreasing absolute numbers of death while the population is increasing in size over time.

Computations by this author from Statistics South Africa's data indicate that the percentage of persons aged 60 years and over increased from about 7% in 1996 to about 8% in 2011. In view of this, the absolute numbers of deaths should increase over time all other things constant. Xunjie et al. (2020) observed that the 12 million additional global deaths in 2017 compared to 1990 were associated with population ageing. The South African trend in the official numbers of deaths therefore raises doubt about the integrity of the officially published numbers post 2006 from the vital registration system.

Under- representation of the number of deaths in a population gives a false sense of the health status in that population, whereas over representation of the number of deaths at any period downgrades the position of the country's human development index (HDI) in comparison with other countries because mortality is one of the inputs in computing the HDI (see Somers et al. (2007)). Holding other things constant, under or over-representation of the number of deaths in population projections biases population projections and if the numbers from such projections are used for planning, could result in inefficient allocation of scarce resources. In view of these implications, it is important to evaluate the integrity of officially published mortality figures from a vital registration system.

AIM and Objectives

The overall aim of this study, therefore, was to evaluate the integrity of the officially published numbers of deaths from South Africa's vital registration system. The specific objectives were to:

Primary Objective

1. Assess the completeness of reporting of deaths in South Africa's vital registration system for the period 2017 at national and provincial levels.

Secondary Objective

2. Estimate the levels of mortality with specific focus on infant mortality rate, probability of dying under-five years (under-five mortality rate) as well as the probability of dying between age 15 and 60, and life expectancy at birth in 2017 at national and provincial levels adjusting for underreporting of deaths.

The research questions arising from the specific objectives were:

(A) What were the magnitudes of overall underreporting of deaths if any, at national and provincial levels in 2017 in South Africa's vital registration system? Is there any indication of induced underreporting of deaths in the data? (Induced underreporting is defined in the methods section).

(B) What were the magnitudes in national and provincial levels of mortality in 2017 in South Africa based on the vital registration system after adjusting for underreporting of deaths?

DATA AND LIMITATIONS

The analysis in this study utilised data from South Africa's vital registration system. Vital registration in South Africa dates back to 1924 (Khalfani, Zuberi, Bah & Lehohla 2005). It is a requirement by law in South Africa that all deaths and their causes are notified to the Department of Home Affairs. A death certificate is required before a burial order is issued for the burial of a deceased. This underscores the imperative for a death to be notified to the appropriate authorities by the deceased's relative. Statistics South Africa processes the death notification forms from the Department of Home Affairs using the 10th revision of the International Classification of Diseases (ICD-10) during which the underlying causes of death are derived using the Automated Classification of Medical Entities software programme. Whether all the reported deaths by the deceaseds' relatives are included in the officially published reports on deaths is another matter and partly what this study attempted to unveil.

Although the systematic official compilation of causes of death began in 1997, the analysis in this study utilised the death records for the period 2000 - 2017 with specific focus on 2017. Data for 1997 – 1999 were excluded from the analysis because completeness of reporting of deaths was lower during that period (Udjo 2017a). The years 2000-2017 were a pre-COVID-19 period. The 2017 death records were the most current publicly available data set from the vital registration system at the time this study commenced. In 2017, a total of 446,544 deaths excluding still births were officially published as the deaths that occurred in the country during that period.

Well-known limitations of death records in vital registration systems include coverage. Usually, it means that not all parts of the country, especially the rural areas, are covered by the registration system. Where vital registration system exists, incomplete coverage could mean that underreporting of deaths exists. According to Groenewald et al. (2005) completeness of reporting of deaths in South Africa's vital registration increased over time and was over 90% in the early 2000s. Misclassification of causes of death is another limitation though not relevant in this study. Since the first confirmed case of COVID-19 in South Africa was on 5 March 2020, the death records analysed in this study do not capture COVID-19 related deaths.

METHODS

Analytical Approach

Underreporting of deaths as stated above, is a common problem in vital registrations systems. In the process of evaluating the integrity of the officially published numbers of deaths, I provided two new concepts in this study to distinguish between two types of underreporting: uninduced and induced underreporting of deaths. Uninduced underreporting is a situation in which no relative of the deceased reported the death in the official registration system. Uninduced underreporting of death is synonymous with the traditional incomplete reporting of deaths in vital registration systems. If uninduced underreporting is not detected in the data and adjusted for, mortality levels will be underestimated in the population.

Induced underreporting relates to a situation in which some of the deaths that were formally reported by relatives of the deceased to the appropriate authorities, were not included in the officially published data due to administrative weaknesses/decisions in the processing and compilation of the data on deaths. Thus, induced underreporting is defined in this study as underrepresentation of the reported number of deaths introduced into the data by the establishments responsible for the processing, compilation, and publishing of reports on deaths in the vital registration system.

In examining the integrity of officially published figures of deaths from a vital registration system, underreporting of deaths should therefore be partitioned into induced and uninduced underreporting. If induced underreporting is present in the data, this would exaggerate overall underreporting of deaths in the vital registration system. The two types of underreporting may be present in the data, but demographers have traditionally focused only on uninduced underreporting. If uninduced underreporting is present, it should have a random pattern but induced underreporting if present and if greater than uninduced underreporting, may produce a systematic pattern in the trend.

Evaluating Completeness of Reporting of Deaths

There are methods that can be used to assess the presence and magnitude of uninduced underreporting of deaths in vital registration systems. Induced underreporting of deaths is, however, more difficult to detect. A systematic decline overtime in the absolute number of deaths in officially published numbers should be regarded as a strong indication of the presence of induced underreporting in the data unless in situations where the population is known to be declining in absolute size, and if ageing of the population is established to have halted. The latter is unlikely demographically. This is because populations age, albeit gradually.

The Growth Balance Method (GBM) is a well-known model for evaluating and estimating the completeness of reporting of deaths in a vital registration system (or in households in a census or survey). There are other models, for example, the Preston and Coale method. The Preston and Coale method is more sensitive to certain types of age misreporting than the GBM (UN: Manual X, 1983). The GBM was applied in this study. The original formulation of the GBM is given by Brass (1971) and further refined and elaborated among others by Hill (1987). The key features of the model and application are summarised by Udjo (2017b) and reproduced below as follows.

There is a linear relationship of deaths and age distributions that may be expressed as:

$$N(x)/N(x+) = r + k(D(x+)/N(x+)) \quad ....(1)$$

Where $N(x)$ is the number of persons at exact age x, $N(x+)$ is the total number of persons above age x, $D(x+)$ is the total number of deaths occurring to persons aged x and over, and r is the growth rate. This implies that there should be a straight-line relationship of intercept r, slope k, a coefficient of the estimated ratio of true to reported deaths (a factor representing the completeness of reporting of deaths. The model assumes that the population is (1) closed to migration, (2) demographically stable, (3) completeness of death recording is constant at all ages after childhood, and (4) completeness of census coverage was constant at all ages (Hill, 1987). Concerning the migration assumption, if there were substantial net migration in the population under study, this would be discernible in the pattern produced in the application of the method to the data: upward arching of the points denoting net immigration or downward arching of the points denoting net emigration (Udjo 2017b).

Regarding the assumption of "demographically stable", it has been observed, based on simulations, that the bias introduced in the estimation of the coefficient of the completeness of reporting of deaths is relatively small (see UN, 1983) cited in Udjo (2006). A careful examination and selection of the points in fitting the model can overcome the violation of assumptions 3 and 4 above (see Udjo, 2006).

In the application of the method, $N(x)/N(x+)$, synonymous to a partial birth rate (the numerator derived from the population estimates produced by this author, (see Udjo, 2020 for details)) was plotted against $D(x+)/N(x+)$, synonymous with a partial death rate (see Brass, 1971). If no errors in the data, the plot should lie on a straight line if the assumptions underlying the model are not seriously violated. A straight line was fitted to the "best" points. The slope and intercept of the straight line were then computed. The completeness of death registration, c was then derived from the slope as $1/k$. The "best" fitting points corresponded either to the age range 35-70 years (in most cases), or 40-65 years (in the case of the Eastern Cape and the Free State Females), or 45 – 70 years (in the case of the Western Cape) except in the case of KwaZulu Natal and the Northern Cape where the "best points" corresponded to the age range 30 – 70 years and 20 – 70 years respectively.

Estimating the Magnitude of Induced Underreporting

The GBM does not separate induced from uninduced underreporting but the magnitude of induced underreporting of deaths was deduced as:

$$IU\% – (100 – E\%) \quad \ldots\ldots\ldots\ldots(2)$$

Where:

IU% = Estimated percent underreporting (induced + uninduced),

E% = Percent expected completeness of death reporting (from other studies).

Estimating Adjusted Absolute Number of Deaths

The adjusted total absolute numbers of deaths were estimated as:

$D' = D + ((1- c) * (D))$ ………………(3)

Where D' is the adjusted total absolute number of deaths, D is the officially published total absolute number of deaths, c is the estimated coefficient of completeness of underreporting of deaths.

Estimating Life Tables Indicators of Mortality

Infant, ${}_1q_0$ and under-five mortality, ${}_5q_0$ rates as well as the probability of dying between age 15 and 60, ${}_{15}q_{45}$, and life expectancy at birth, e_0 were computed using life table methods. Construction of life table functions from mortality data are described in various demography text books including Preston et al. (2001). Life table functions are interrelated and the starting point in the construction of a life table is age specific death rates. In this study, the life tables were based on the adjusted age-specific death rates derived from the application of the GBM to the data. The adjusted age specific death rates were estimated as:

$ASDR_a' = ASDR_a + (ASDR_a * (1-c))$ ………(4)

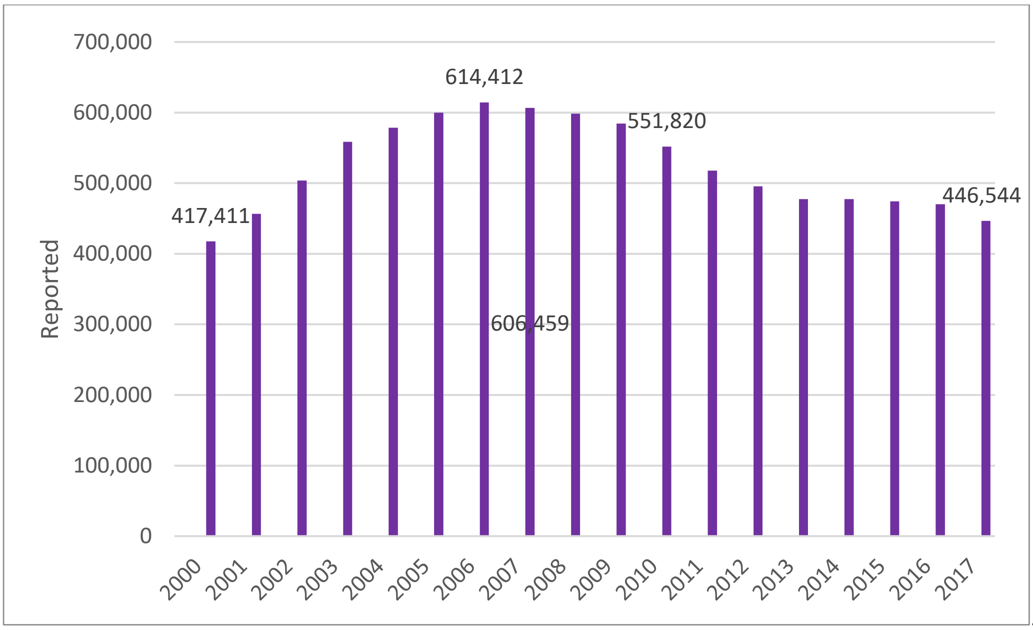
Where $ASDR_a'$ is the adjusted age specific death rate for an age group a, $ASDR_a$ is the unadjusted age specific death rate for that age group.

RESULTS

Contextualising Assessment of Completeness of Death Registration: Trend in Official Numbers of Reported Deaths Nationally and Provincially.

Figure 1 shows the officially published number of reported deaths during the period 2000 – 2017. It suggests that the absolute numbers of reported deaths nationally increased from 417,411 in 2000 to 614,412 in 2006 and began a downward trend in 2007 reaching a value of 446, 544 in 2017. As already noted, the trend after 2006 is odd even if some people with HIV were living longer with ART. With increasing size of a population over time, the trend in the absolute numbers of deaths in the population should be upward. Although ART rollout should reduce the absolute number of HIV/AIDS-related deaths over time, this should not cause an inversion in the trend. Large scale (i.e., covering most of the population that needs it) rollout of ART is expected to reduce the gradient of the slope of the trend in the absolute numbers of deaths.

Figure 1: Official Numbers of Reported Deaths nationally 2000 – 2017.



A

Tables 1a-b illustrate the relationship between population increase, aging and absolute number of deaths in some selected countries in Europe and Africa. The countries in the table, are ageing populations (compare the percentage of the population aged 60 years and over in 2006 with the corresponding figure in 2017). Also, the populations are growing (compare population size in 2006 with the corresponding figure in 2017). Consequently, the absolute number of deaths increased in 2017 compared with the corresponding number of deaths in 2006. The South African pattern is, however, contradictory to this.

Table 1a: Absolute Numbers of Reported Deaths in Selected Countries 2006

Country	Population Size**	% Population 60+*	Number of Deaths**
United Kingdom	60,821,356	21.2	589,663
New Zealand	4,185,888	16.4	28,389
Switzerland	7,457,958	21.3	61394
Sweden	9,096,165	23.5	92,344
Canada	32,536,987	17.9	228,079
France	61,508,926	20.9	536,542
Egypt	76,873,663	7.1	489,455
Mauritius	1,228,089	9.6	8,518

Sources:
* United Nations Population Prospects, nearest date to 2006 and 2017.
** National Statistical Offices, Macrotrends (www.macrotrends.net) derived from crude death rates.

Table 1b: Absolute Numbers of Reported Deaths in Selected Countries 2017

Country	Population Size**	% Population 60+*	Number of Deaths**
United Kingdom	66,727,461	23.3	621,500
New Zealand	4,702,034	20.0	33,339
Switzerland	8,455,804	23.5	67,849
Sweden	9,904,896	25.2	91,501
Canada	36,732,095	22.3	276,689
France	64,842,509	25.0	594,087
Egypt	96,442,591	7.7	568,047
Mauritius	1,264,499	15.4	10,261

Sources:
* United Nations Population Prospects, nearest date to 2006 and 2017.
** National Statistical Offices, Macrotrends (www.macrotrends.net) derived from crude death rates.

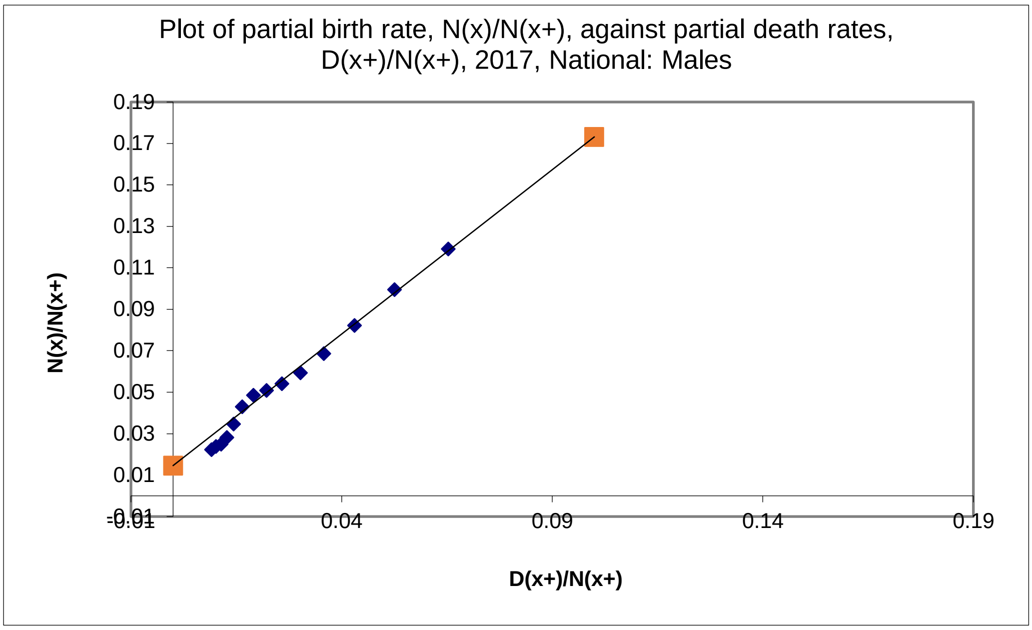
Turning again to ART as a probable factor in the South African pattern, consider the following. The rollout of ART in the public health system in South Africa commenced in 2004 (de Paoli et al. 2012), and Figure 1 indicates there was a decrease of 4.8% in absolute number of deaths between 2004 and 2007 i.e., three years after ART rollout in the public health system began. For ART to have substantial impact on HIV/AIDS-related mortality in a population, most people who need ART should be taking ART (i.e., high coverage irrespective of personal and religious beliefs) and consistently (i.e., irrespective of side effects). According to UNAIDS (2010) estimates, coverage of antiretroviral therapy in South Africa in 2010 with CD4 count <350 among children was about 54% and 36% among adults. According to the same source, adult coverage of antiretroviral therapy in South Africa in 2016 with CD4 count <200 was 56%. From these figures, it was not the case that most people who needed ART were taking ART in 2010 or 2016 in South Africa. According to a study, standardised crude death rates from HIV/AIDS as underlying cause of death increased during the period 2000 – 2013 (Udjo 2017b).

Appendices 1 – 9 show the decomposition of the trend in the official numbers by province of residence. The province of residence was not indicated in some of the official number of reported deaths. For example, in 2017, the province of residence was not indicated in 5,144 deaths. As seen in Appendix 9 (the Western Cape), the trend in the absolute number of deaths is consistent with expectation – increasing number of deaths with time though this does not necessarily imply that induced underreporting was non-existent in the Western Cape data. The trend in the other provinces deviate from expectation and more glaringly in the Free State, KwaZulu-Natal, and Mpumalanga (Appendices 2, 4, and 6). If ART were the reason for deviation of the scatter plot from the usual expectation, then one would have also expected the Western Cape to exhibit inversion in the trend in the absolute number of deaths like the other provinces. Let us now focus specifically on the 2017 data.

Model Evaluation of Completeness of Reporting of Deaths, 2017.

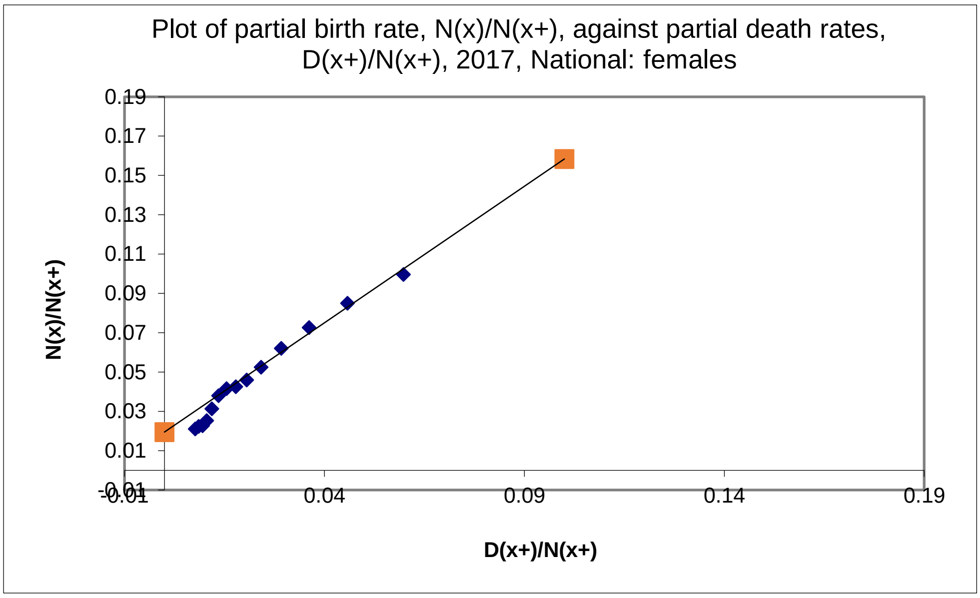
Figures 2a-b summarise the results of fitting the GBM to the officially published numbers of deaths for 2017 at national level. The results for the provinces are summarised in Appendices 10a - 18b. Three patterns are evident from the graphs: (1) Steeper gradient of the scatter plot for the younger persons (less than 35 years old) than for the older persons as seen in the Eastern Cape (Figures 10a-b), KwaZulu-Natal (Appendices 13a-b), Limpopo males (Appendix 14a). (2) A downward slope in the scatter plot corresponding to younger persons as seen in Gauteng (Appendices 12a-b) and to a lesser extent, in the Western Cape (Appendices 18a-b). (3) All the points in the scatter plot are approximately linear as seen in the North West (Appendices 16a-b) and the Northern Cape (Appendices 17a-b). Pattern (3) is the usual expectation with varying degrees of outliers. Patterns (1) and (2) are unusual especially pattern (1) and make the interpretation of the results difficult. It is tenous to attribute patterns (1) and (2) to violation of the assumptions underlying the model. For example, if the unusual pattern were due to violation of the assumption of "demographically stable", then the scatter plots for males and females in Limpopo should be similar (Appendices 14a and 14b). Also, if the unusual pattern were due to violation of the assumption of "population closed to migration", the scatter plots for Gauteng (Appendices 12a-b) should have exhibited upward arching and corresponding downward arching of the scatter plots for Limpopo (Appendices 14a and 14b) since Gauteng is a major receiving province of out-migrants from Limpopo. The unusual patterns are probably mainly due to varying degrees of induced underreporting between provinces and between males and females. Further evidence of this is provided in the following section.

Figure 2a: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, National: male



Source: Author’s computation from Statistics South Africa’s Death Records Files

Figure 2b: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, National: females



Source: Author’s computation from Statistics South Africa’s Death Records Files

Table 2 summarises the estimated completeness of the officially published numbers of deaths for 2017. The reciprocals of the estimates constitute the magnitudes of induced plus uninduced underreporting of deaths in the official numbers. Since as noted above, the best fitting points in the application of the GBM corresponded to adult ages, the estimated completeness of death should be interpreted as the completeness of reporting of adult deaths.

The results are revealing. The estimated completeness of reporting in 2017 nationally was about 63.1% for males (i.e., only 63.1% of the male deaths that occurred in that year were apparently reported) and 72% for females (i.e., only 72% of the female deaths that occurred in that year were apparently reported). Taking into account Groenewald et al.'s (2005) estimates for the early 2000s and considering that reporting of deaths may have been higher for adults compared with children, the estimated completeness of reporting suggests that completeness of reporting of deaths declined in 2017 in comparison with the early 2000s. This is illogical. One would expect improvement in completeness of reporting deaths over time in a vital registration system. Also, one would expect the magnitude of uninduced underreporting to diminish over time in the absence of induced underreporting. The estimated completeness of reporting of deaths in 2017 at national level implies that in that year, induced plus uninduced underreporting of deaths amounted to about 36.9% and 28.0% of the actual number of deaths that occurred among males and females, respectively in South Africa in 2017.

The estimated completeness of reporting of deaths as seen in Table 2, implies that at provincial level, the percentage of male deaths that occurred in 2017 that were reported ranged between 56.3% (Eastern Cape) and 80.6% (Limpopo) while for females, the corresponding percentage ranged between 57.0% (Eastern Cape) and 93.2% (Limpopo). Apart from female deaths in Limpopo, the levels of completeness of reporting of deaths implied by the estimates are low. The differences in the provincial figures partly suggest that the magnitude of induced underreporting of deaths in 2017 was least severe in Limpopo compared to the other provinces.

Assume Groenewald et al.'s (2005) completeness of reporting of deaths in the early 2000s to be the most conservative level of completeness of reporting of adult deaths to have expected in 2017. Using the formula given above, at national level, the percentage of induced underreporting among adult males in 2017 was estimated as at least: 36.9 – (100-90) = 26.9% and for adult females, at least: 28 – (100-90) = 18.0%.

Table 2: Estimated Percent Completeness of Adult Completeness of Death Reporting and Underreporting, 2017

National/Province	Males		Females	
	% Completeness	% Induced+Uninduced Underreporting	% Completeness	% Induced+Uninduced Underreporting
National*	***63.1***	***36.9***	***72.0***	***28.0***
Eastern Cape	56.3	43.7	57.0	43.0
Free State	70.3	29.7	65.3	34.7
Gauteng	58.4	41.6	71.5	28.5
KwaZulu-Natal	56.6	43.4	67.6	32.4
Limpopo	80.6	19.4	93.2	6.8
Mpumalanga	60.2	39.8	72.5	27.5
North West	60.5	39.5	70.4	29.6
Northern Cape	59.7	40.3	64.0	36.0
Western Cape	60.5	39.5	66.3	33.7

* Independently estimated (i.e., not a weighted provincial average).
Source: Author's computation from Statistics South Africa's Death Records Files.

At national level, the estimates suggest that at least about 26.9% and 18.0% respectively of the adult male and female deaths that were reported by the deceaseds' relatives in 2017 were not included in the officially published figures for the year 2017. Assume completeness of reporting of deaths in late 2000s were higher than in the early 2000s, say 94%, induced underreporting of deaths in 2017 for males would be 30% instead of 26.9%. It is unlikely that completeness of reporting of deaths in late 2000s remained stagnant at the level in the early 2000s. This suggests that the magnitudes of induced underreporting in the officially published number of deaths from the vital registration system post 2006 were substantial. Similar computations may be made at provincial level, but one needs to be cautious about the expected level of completeness of reporting of deaths at provincial level.

Model Estimates of Mortality from Reporting of Deaths, 2017

Mortality indicators for the period 2017 were estimated after correcting for uninduced and induced underreporting. The results are summarised in Table 3. The estimates suggest that the total number of deaths in South Africa in 2017 was probably about 594,853, whereas the officially published number of deaths for that year was 446,544. The model estimates suggest that at least about 135,659 deaths that were probably reported by the deceaseds' relatives in 2017 were not included in the officially published figures for the year 2017.

As seen in Table 3, the estimated life expectancy at birth in 2017 at national level was 59.6 years for males and 67.7 years for females. At provincial level, the estimated life expectancy at birth ranged between 54.1 years (Eastern Cape) and 62.4 years (Gauteng) for males and for females, it ranged between 61.1 years (Northern Cape) and 70.6 years (Western Cape) in 2017.

Table 3 also shows that infant mortality was probably about 23 per thousand live births in 2017, and of every 1,000 children born in South Africa in 2017, 30 were likely to die before their fifth birth day. Furthermore, the table suggests that of males that lived up to age 15 years in 2017, 43% of them were likely to die before they reached the age of 60 years. The corresponding percentage for females is 28%. The estimated infant ($_1q_0$) and under- five mortality ($_5q_0$) rates and probability of dying between age 15 to 60 years ($_{15}q_{45}$) at provincial level in 2017 are also shown in Table 3.

Table 3: Estimated Levels of Mortality Indicators 2017

	Absolute Number of Deaths			**Life Expectancy at birth**		**Adult mortality $_{15}q_{45}$**			
National/Province	**Males**	**Females**	**Total**	**Males**	**Females**	**Males**	**Females**	$_1q_0$	$_5q_0$
National*	***322,517***	***271,677***	***594,853***	***59.6***	***67.7***	***0.429***	***0.281***	***0.023***	***0.030***
Eastern Cape	50,524	44,842	95,366	54.1	63.6	0.581	0.371	0.016	0.025
Free State	21,572	20,085	41,657	54.5	61.5	0.525	0.380	0.037	0.046
Gauteng	70,753	55,241	125,994	62.4	69.0	0.349	0.235	0.026	0.032
KwaZulu-Natal	56,770	49,098	105,869	59.0	68.6	0.344	0.268	0.017	0.023
Limpopo	27,035	24,471	51,506	61.5	67.6	0.411	0.250	0.019	0.028
Mpumalanga	24,059	20,399	44,458	59.0	67.0	0.444	0.314	0.022	0.030
North West	25,335	20,399	45,734	58.1	64.6	0.444	0.340	0.027	0.042
Northern Cape	9,771	8,137	17,907	54.3	61.1	0.428	0.395	0.037	0.048
Western Cape	36,698	29,005	66,362	61.9	70.6	0.378	0.228	0.020	0.023

* Independently estimated (i.e., not a weighted provincial average).
$_1q_0$ = infant mortality rate (using radix =1, figure in table can be converted to per thousand live births)
$_5q_0$ = under five mortality rate (using radix = 1 figure in table can be converted to per thousand live births)
$_{15}q_{45}$ = probability of dying between age 15 and 60.
Source: Author's computation from Statistics South Africa's Death Records Files.

DISCUSSION AND CONCLUSION

Mortality indicators are quantitative measures of mortality levels and are sometimes used in comparing the health status of different populations and sub-groups within a population. The data sources for computing the indicators include reported deaths from vital registration systems as well as reports on household deaths by heads of household (or knowledgeable person) in censuses and surveys. Such data require evaluation. In undertaking such evaluation, population scientists and demographers have traditionally not considered that apparent incomplete underreporting of numbers of deaths, may partly be attributable to administrative weaknesses/decisions in the processing and compiling the data. The conventional approach inherently ascribes incomplete reporting of deaths to those reporting such deaths. This study departed from the traditional approach by providing two new concepts in the evaluation – uninduced and induced underreporting. In this approach, uninduced underreporting of deaths is ascribed to the respondent who may be the deceased relative or head of household reporting on deaths while induced underreporting is ascribed to the establishments processing, compiling, and publishing the information.

The results of the study suggest that there was induced underreporting in the officially published numbers of deaths from the vital registration system in South Africa in 2017. The results suggest that at least about 135,659 deaths that were probably reported by the deceaseds' relatives in 2017 were not included in the officially published figures at national level for the year 2017.

The above figure was a conservative estimate because of the following. The numerator used in the estimation of the partial death rate in equation (1) was based on population estimates by this author. If Statistics South Africa's mid-year estimates were used, the resulting magnitudes of induced underreporting would have been larger because Statistics South Africa's mid-year population estimates for South Africa since 2013 are consistently larger than the corresponding estimates produced by this author. For example, Statistics South Africa's mid-year population estimate for South Africa in 2016 was 55,908,900 (Statistics South Africa 2016b) and was larger by a factor of 1.02 than this author's estimate of 54,636,945 (Udjo 2016) for the same period.

Statistics South Africa (2014) claimed that the level of completeness of adult death registration during the period 2007-2011 was 94%, implying underreporting of deaths of 6% during the period. Statistics South Africa did not provide the graphs or parameter estimates resulting from its analysis in the report. Udjo (2017b), argued that if the GBM were appropriately applied to the data, it is not *(mathematically)* possible to obtain the level of completeness of death registration claimed by Statistics South Africa using the 2011 Causes of Death data and the 2011 Census figures as denominator. This suggests that the levels of completeness of death registration in the official reports on causes of death post 2006 may be suspect considering that there may be induced underreporting in the data.

The estimated mortality levels in this study were computed after adjusting for underreporting based on fitting the GBM to older persons (broadly, persons aged 20 to 70 years). If induced and uninduced underreporting of deaths among younger persons were substantially higher than among the older persons in 2017, then the estimated mortality levels provided in Table 3 for the period 2017 under-estimate mortality levels for the period.

The 2017 data on reported deaths in South Africa do not capture COVID-19 related deaths since the first case of COVID-19 related death in South Africa was reported on 5 March 2020. In the context of COVID-19 fatality therefore, the so called "additional deaths" due to COVID-19 in South Africa need to be computed and interpreted with caution. In the light of the above analysis, if the estimates of such "additional deaths" do not take into account induced underreporting of deaths in the officially published figures on deaths from the vital registration system, the estimates would probably exaggerate "additional deaths" due to COVID-19 in South Africa.

The results of this study in retrospect, raise the question: How reliable are the officially published absolute numbers of deaths from other Statistics South Africa's data sets post 2006, including overall household deaths as well as maternal deaths in the 2011 Census? Further research is required to critically evaluate the integrity of Statistics South Africa's officially published absolute numbers of deaths from its various data sets post 2006. In the light of the results from this study, policy makers and other users of mortality figures for planning and research need to consider that the true number of deaths each year in South Africa post 2006, may be larger by a factor of at least 1.3 than officially published numbers of deaths for each year.

ACKNOWLEDGMENTS

I wish to acknowledge the critical comments of the reviewers of this study: Dr A.S. Adebowale, (Ag. Head of Department of Epidemiology and Medical Statistics, Faculty of Public Health, College of Medicine, University of Ibadan, Nigeria), Dr Naomi N. Wekwete (Department of Demography Settlement and Development, University of Zimbabwe). The views expressed in this paper, however, are those of the author.

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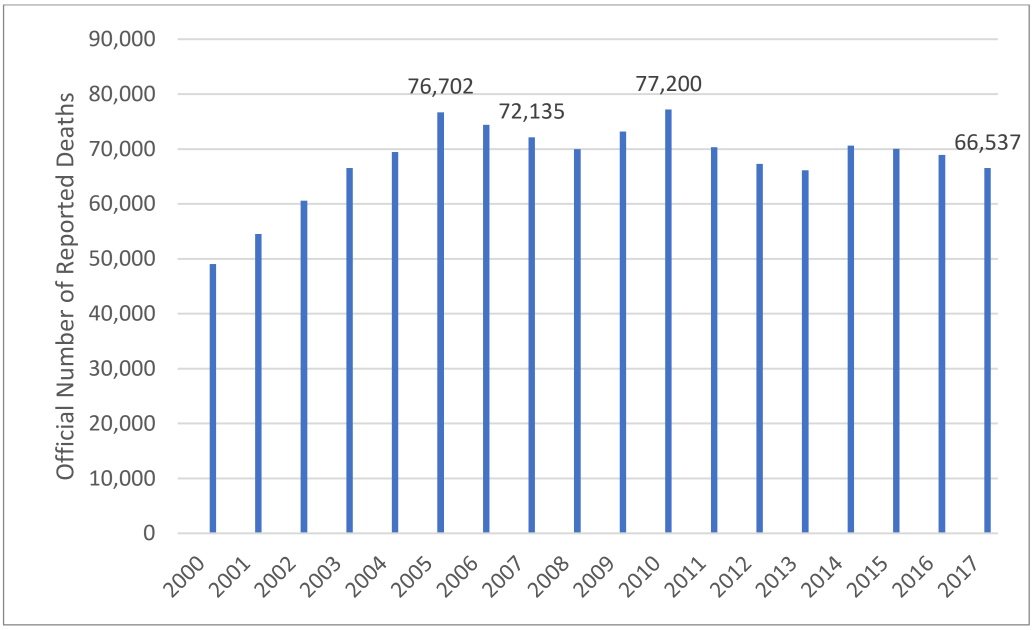
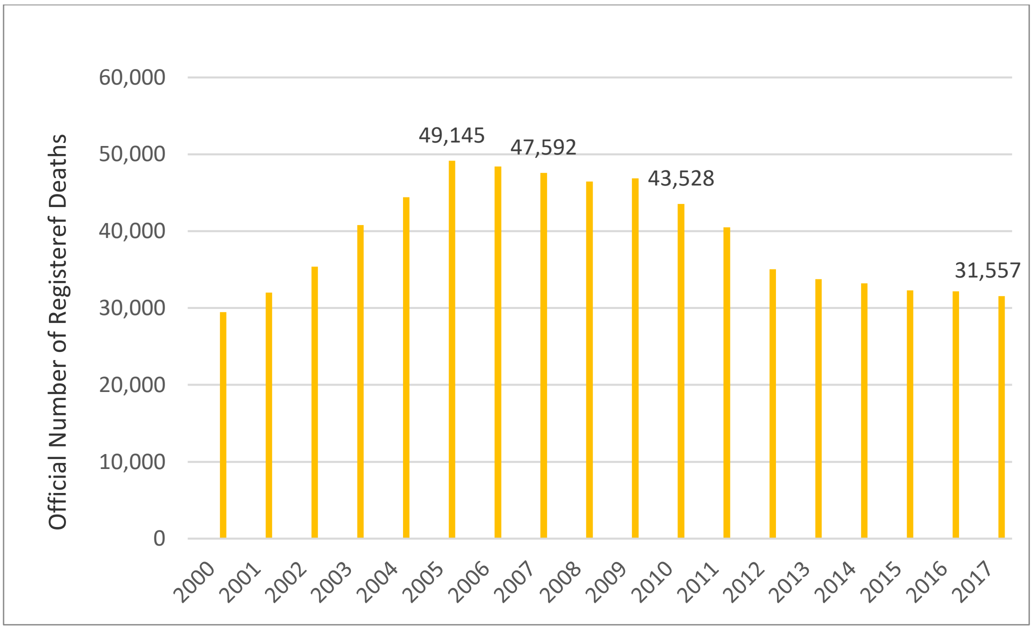
Appendix 1: Official Numbers of Reported Deaths Eastern Cape 2000 – 2017.



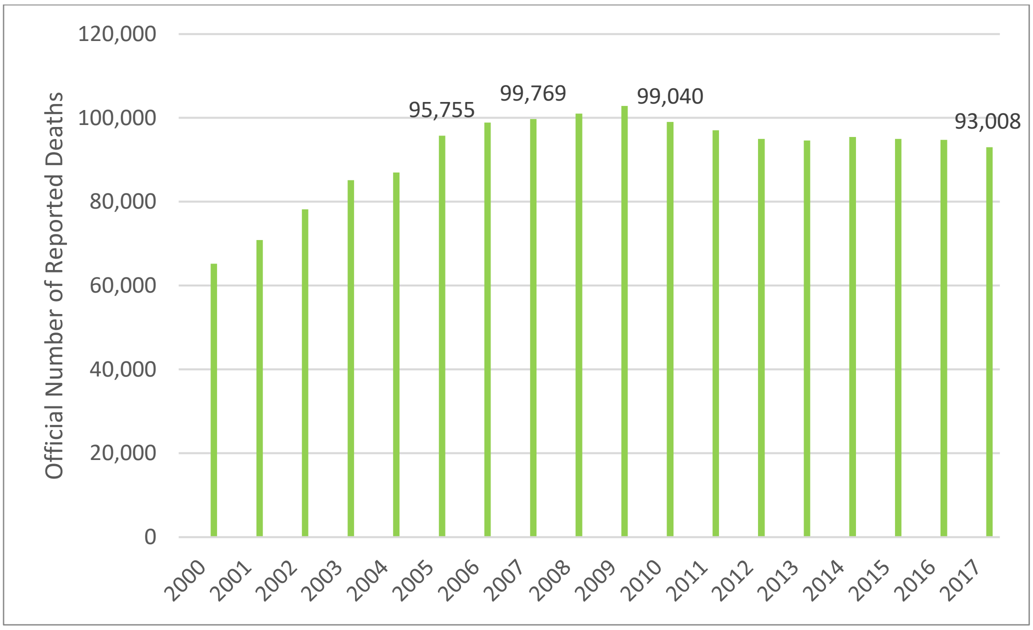
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 2: Official Numbers of Reported Deaths Free State 2000 – 2017.



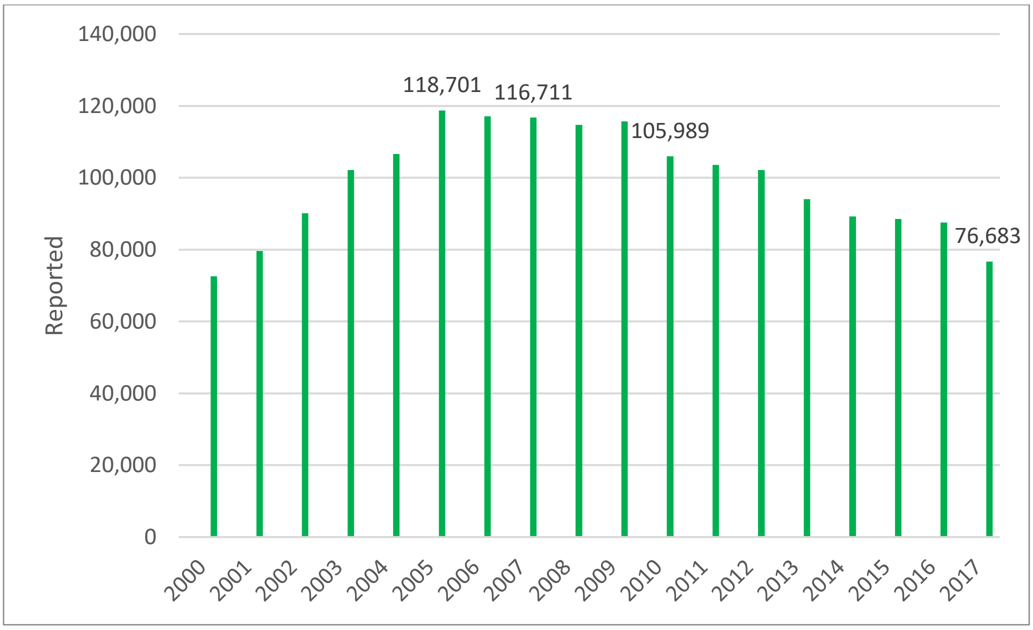
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix3: Official Numbers of Reported Deaths Gauteng 2000 – 2017.



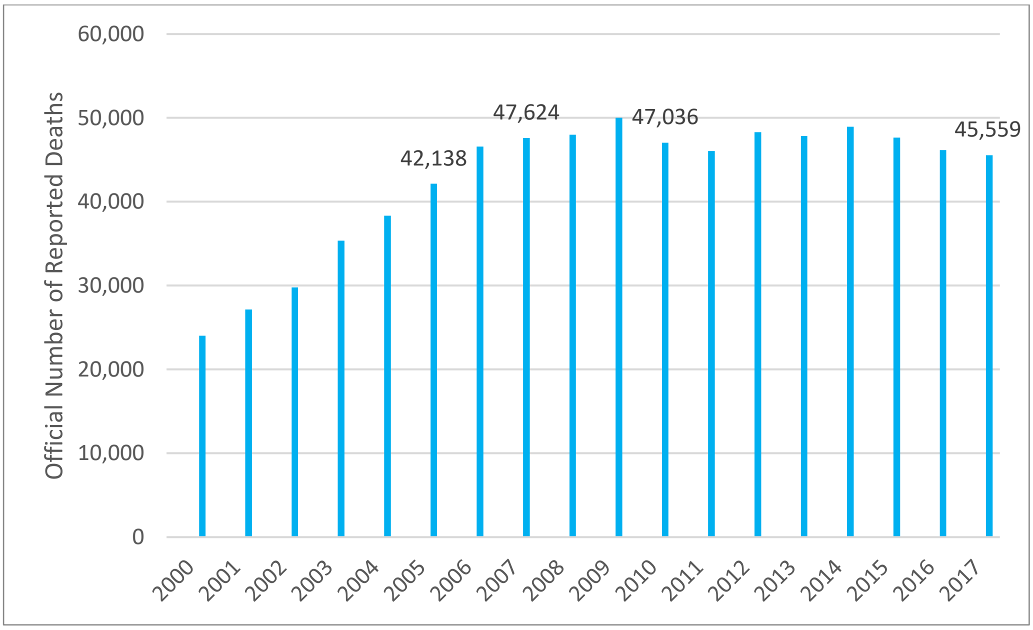
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 4: Official Numbers of Reported Deaths KwaZulu-Natal 2000 – 2017.



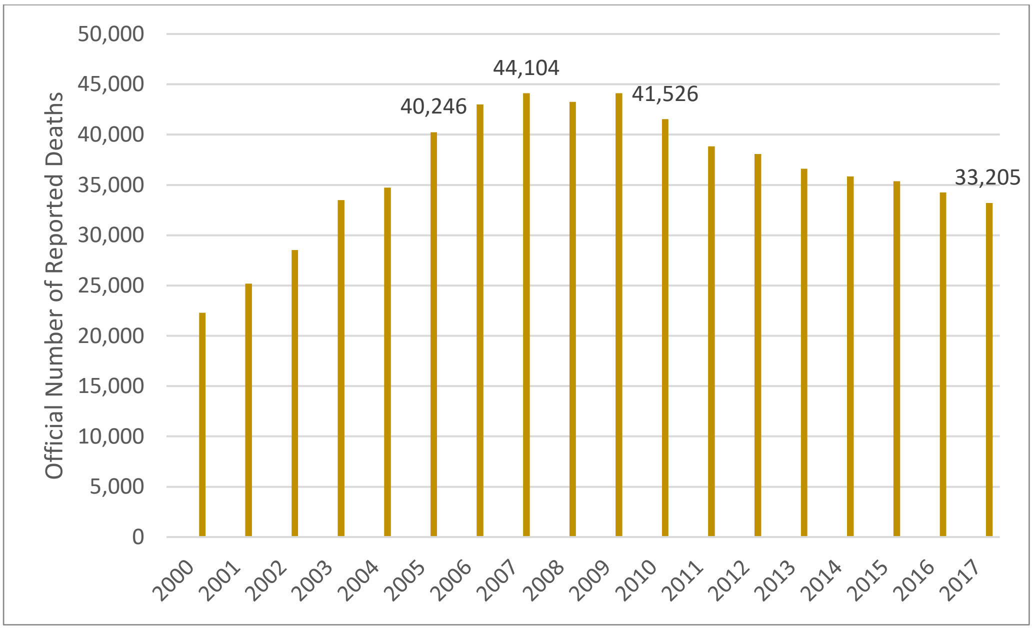
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 5: Official Numbers of Reported Deaths Limpopo 2000 – 2017.



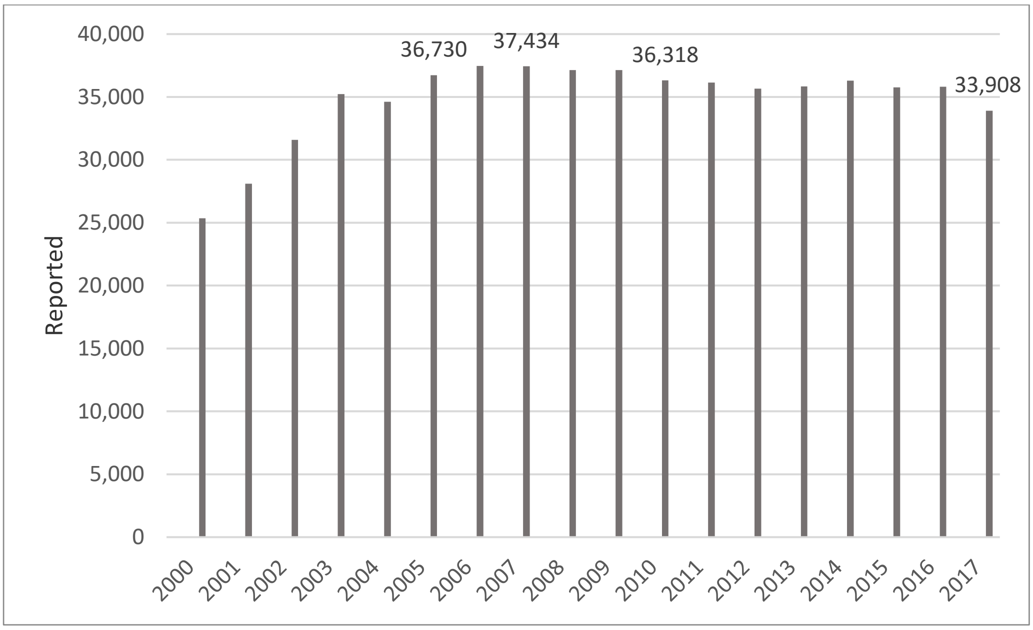
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 6: Official Numbers of Reported Deaths Mpumalanga 2000 – 2017.



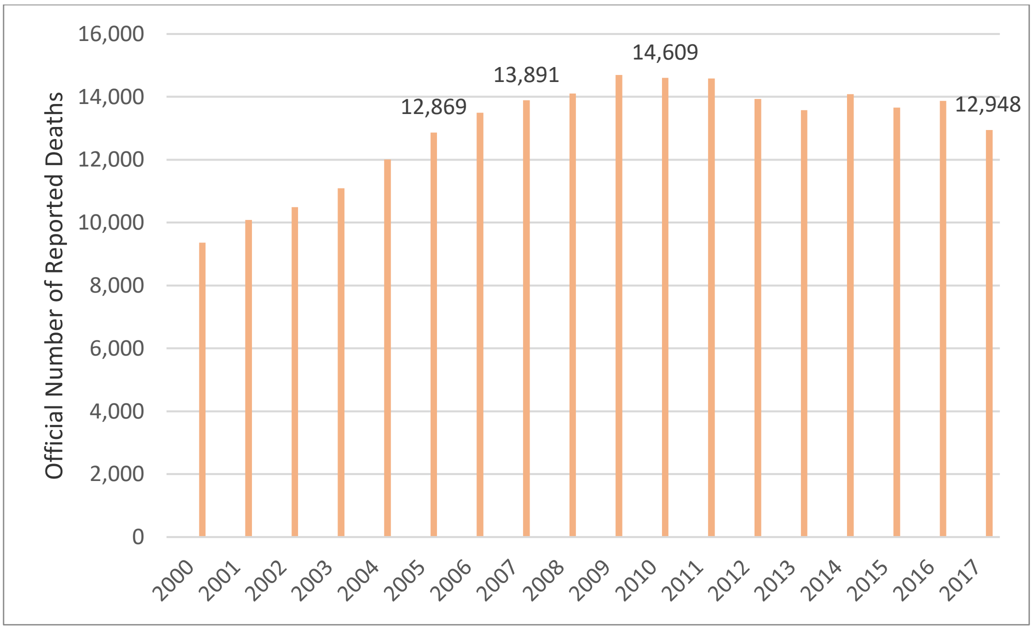
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 7: Official Numbers of Reported Deaths North West 2000 – 2017.



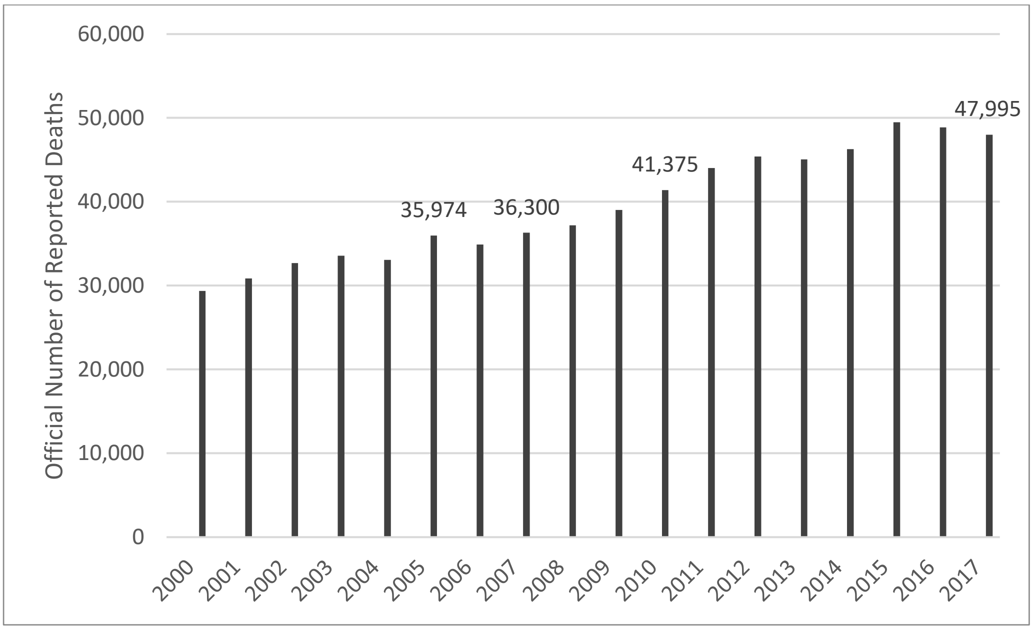
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 8: Official Numbers of Reported Deaths Northern Cape 2000 – 2017.



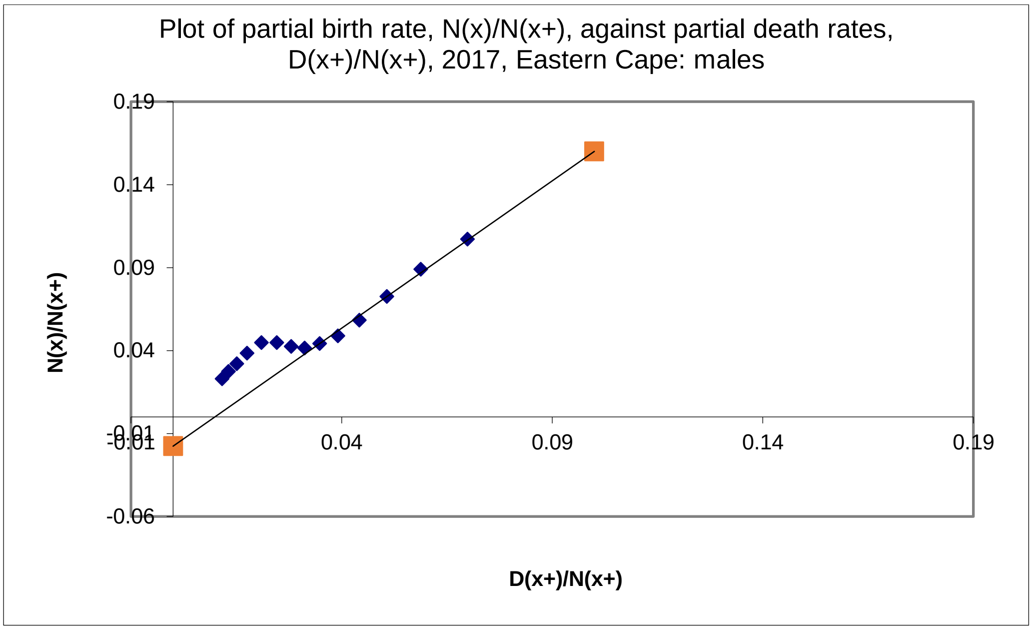
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 9: Official Numbers of Reported Deaths Western Cape 2000 – 2017.



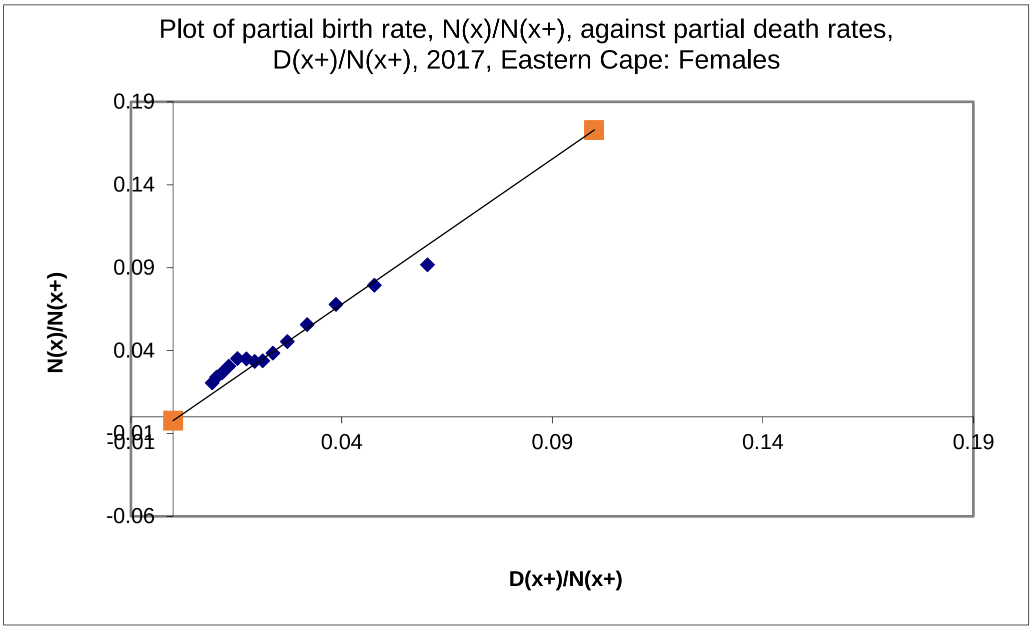
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 10a: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Eastern Cape: males



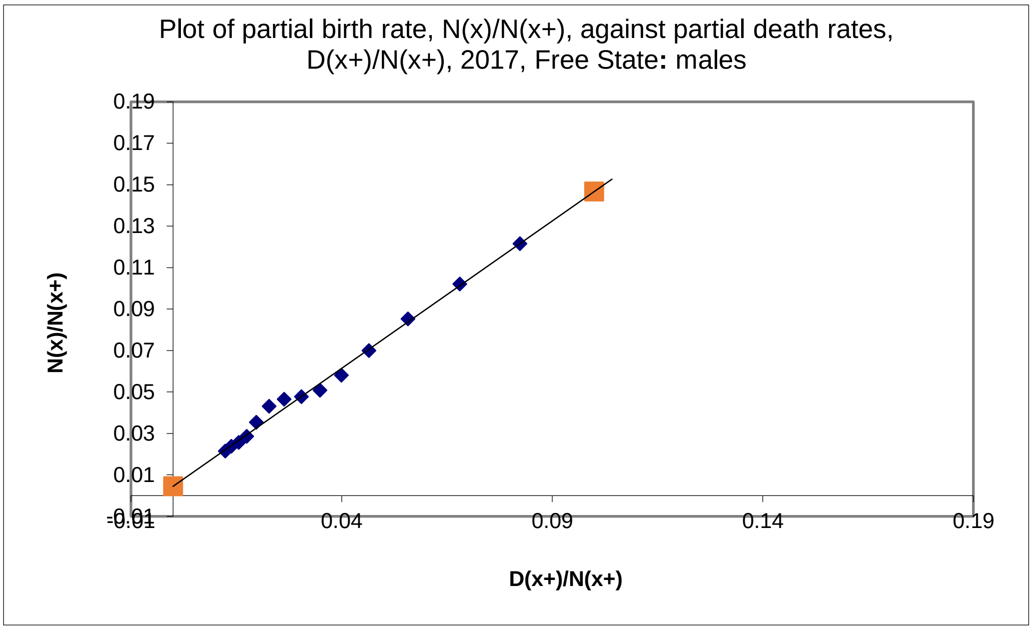
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 10b: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Eastern Cape: females



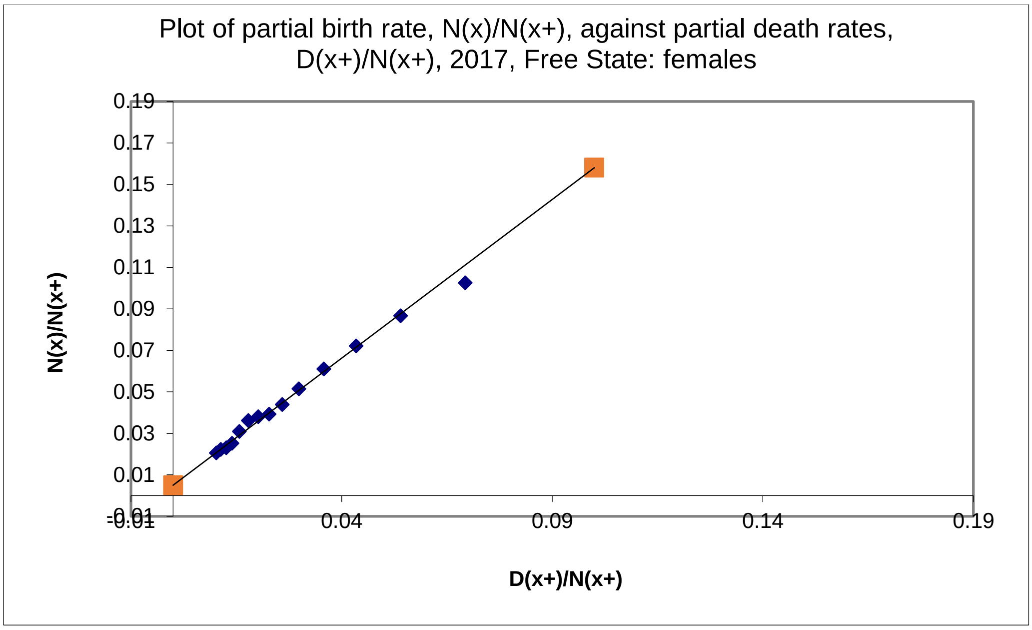
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 11a: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Free State: males



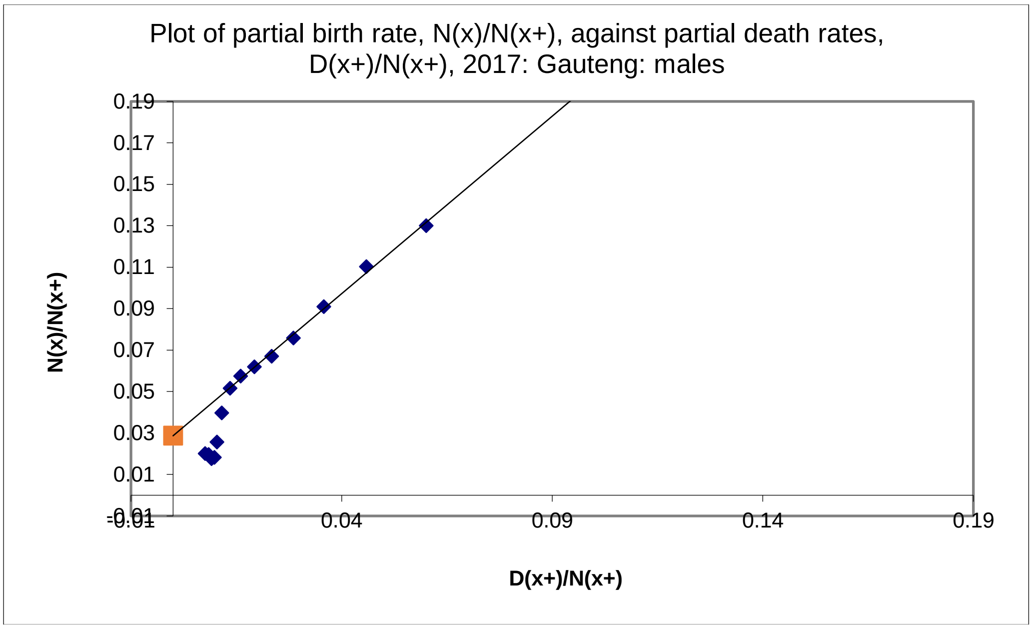
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 11b: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Free State: females



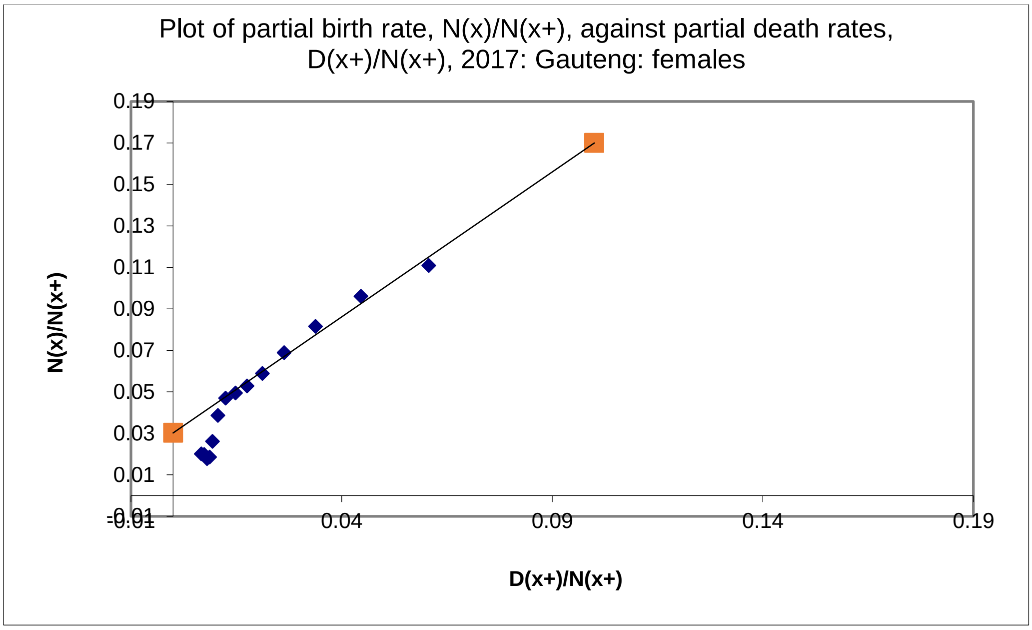
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 12a: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Gauteng: males



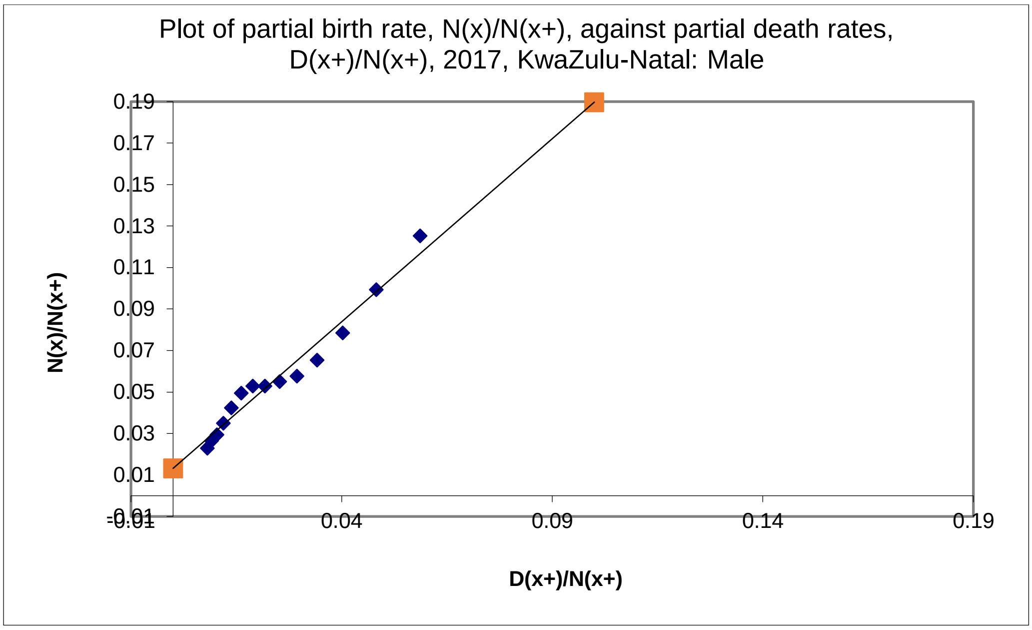
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 12b: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Gauteng: females



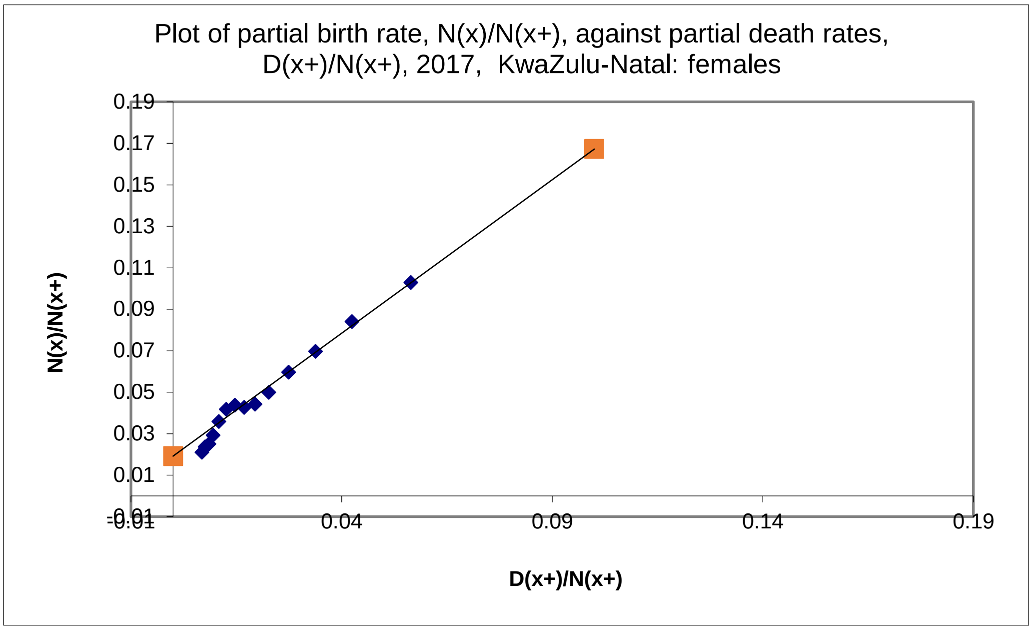
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 13a: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, KwaZulu-Natal: males



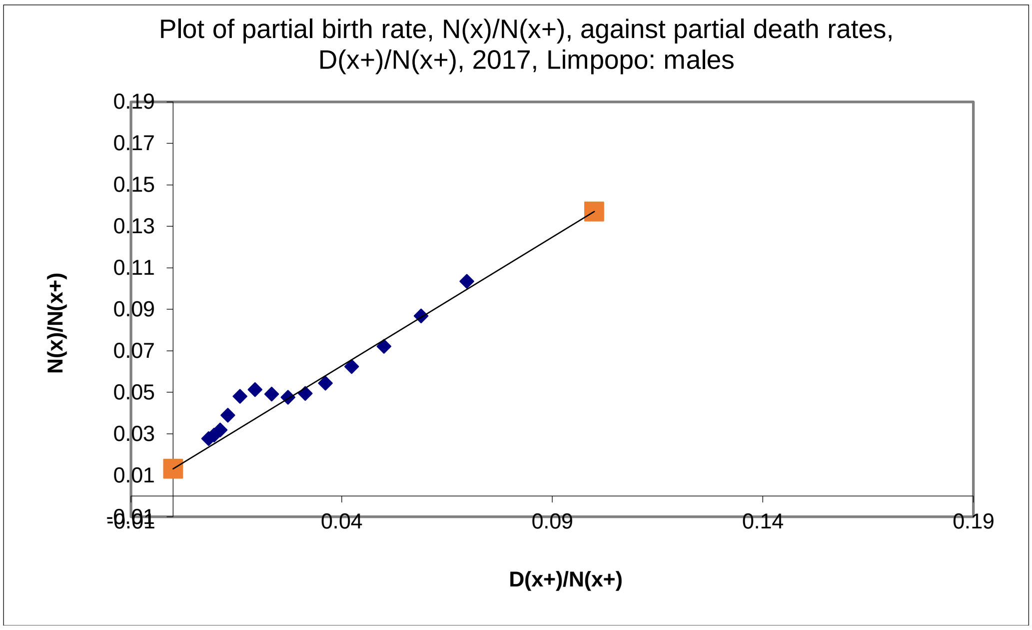
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 13b: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, KwaZulu-Natal: females



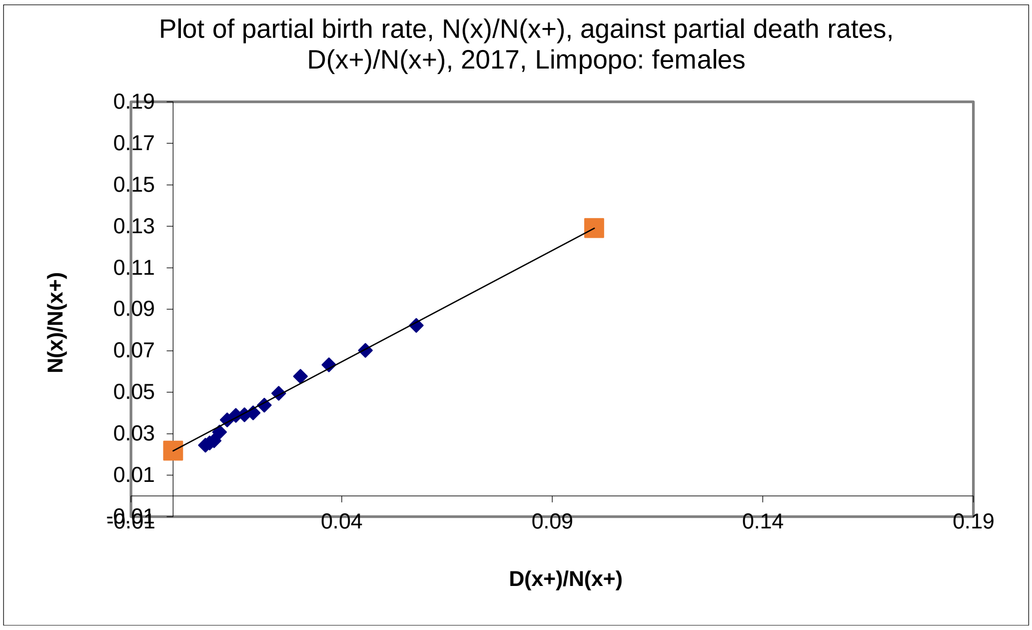
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 14a: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Limpopo: males



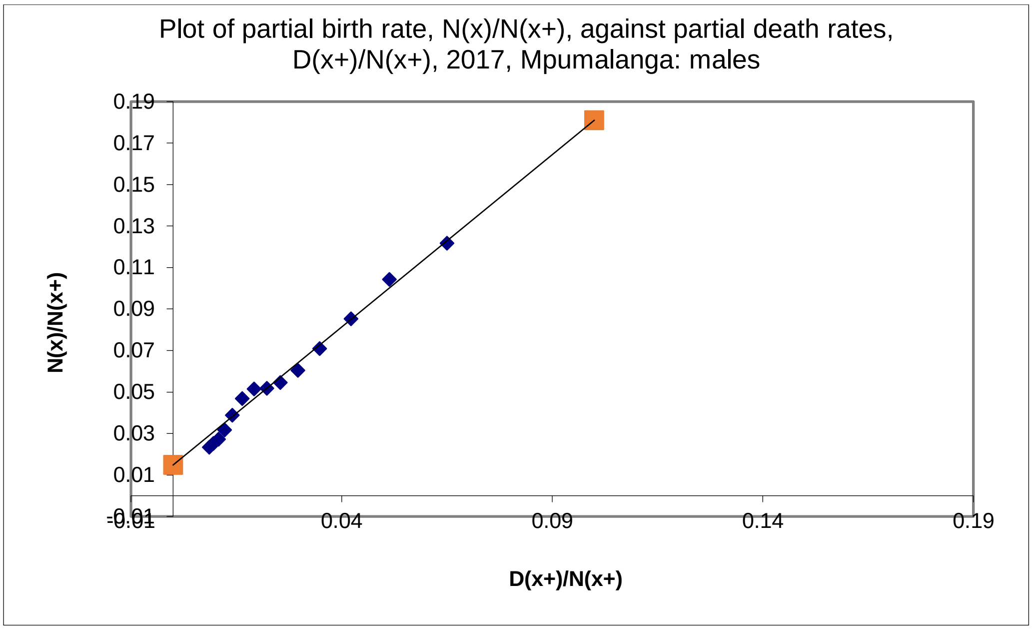
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 14b: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Limpopo: females



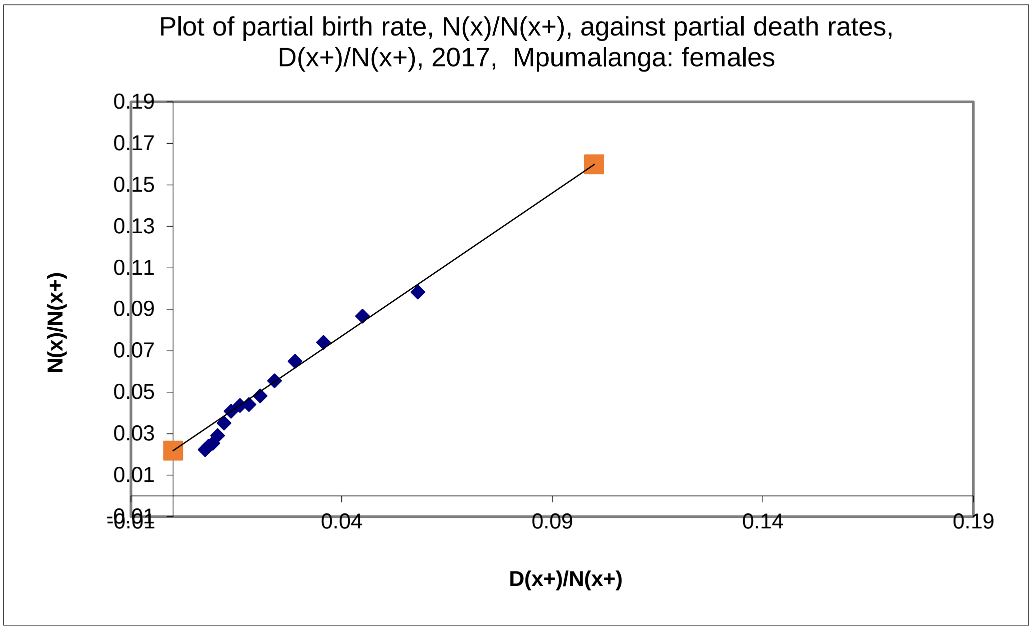
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 15a: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Mpumalanga: males



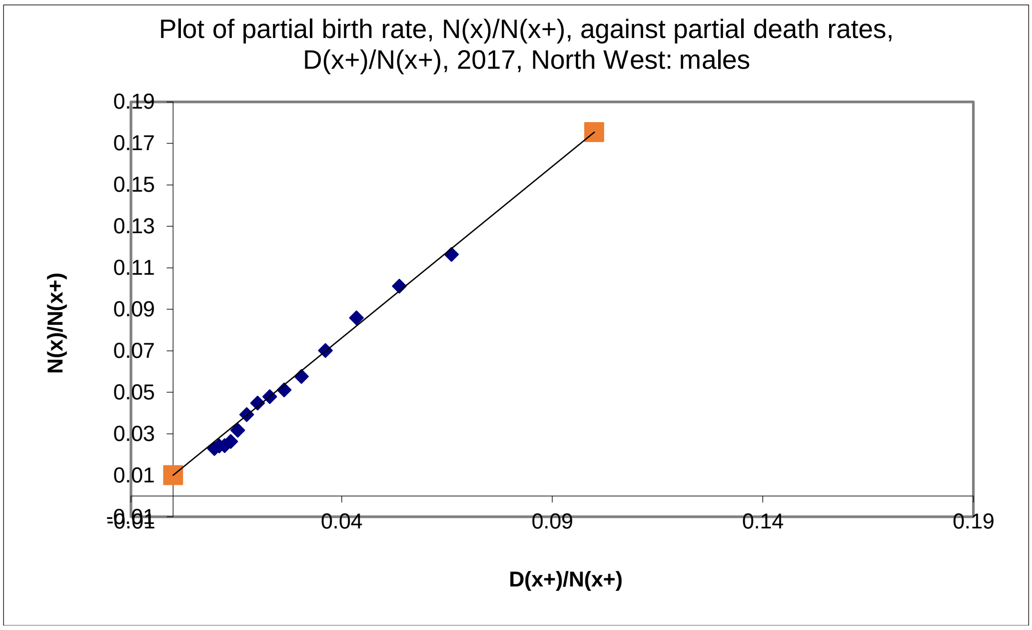
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 15b: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Mpumalanga: females



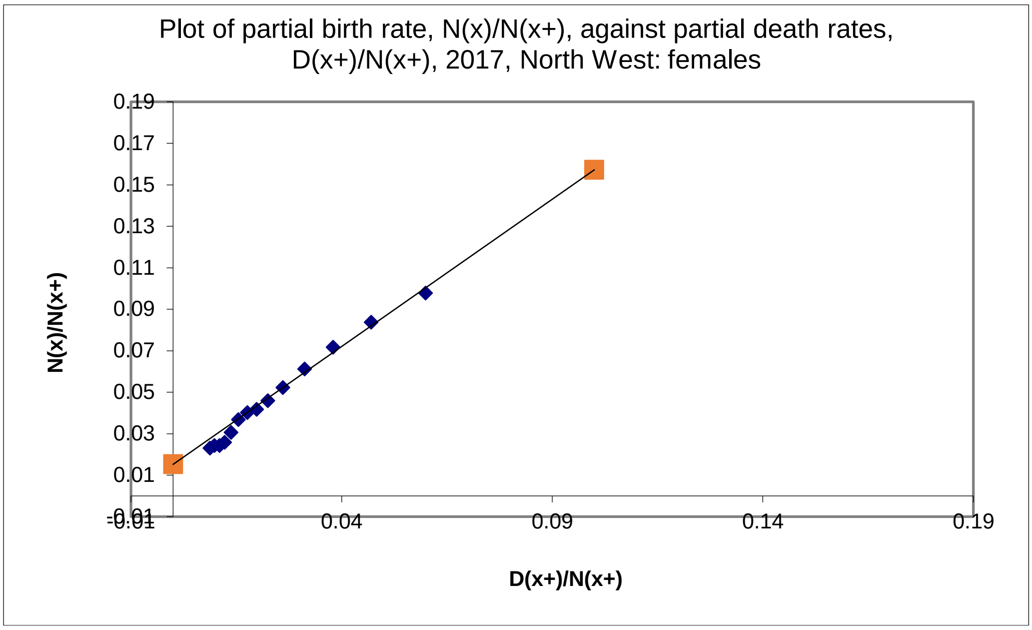
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 16a: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, North West: males



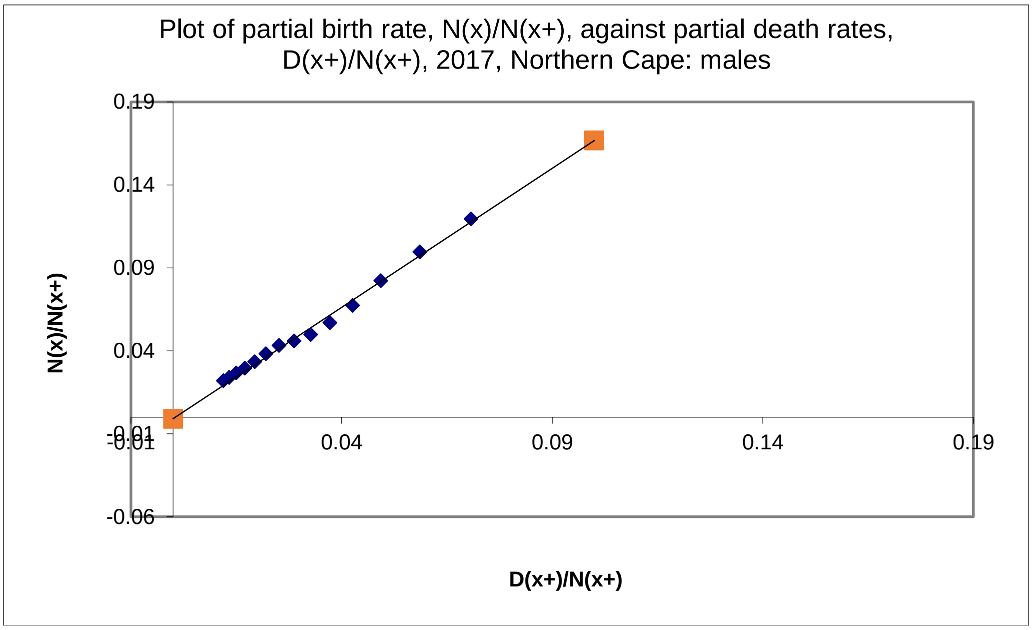
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 16b: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, North West: females



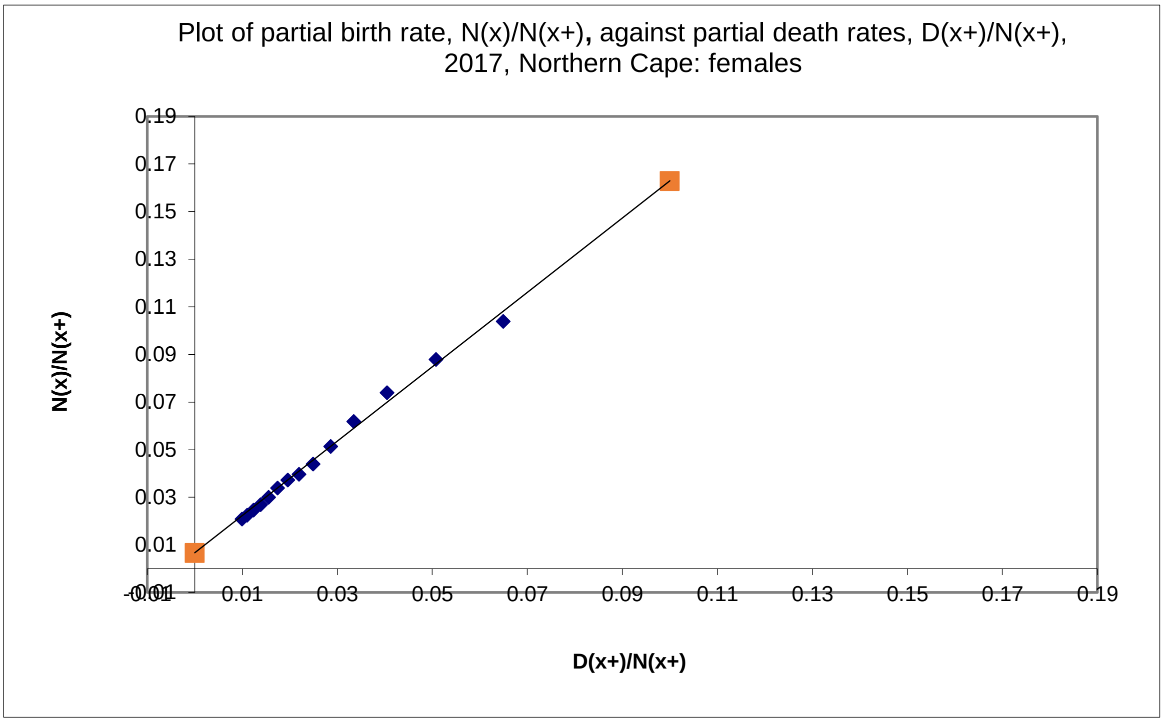
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 17a: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Northern Cape: males



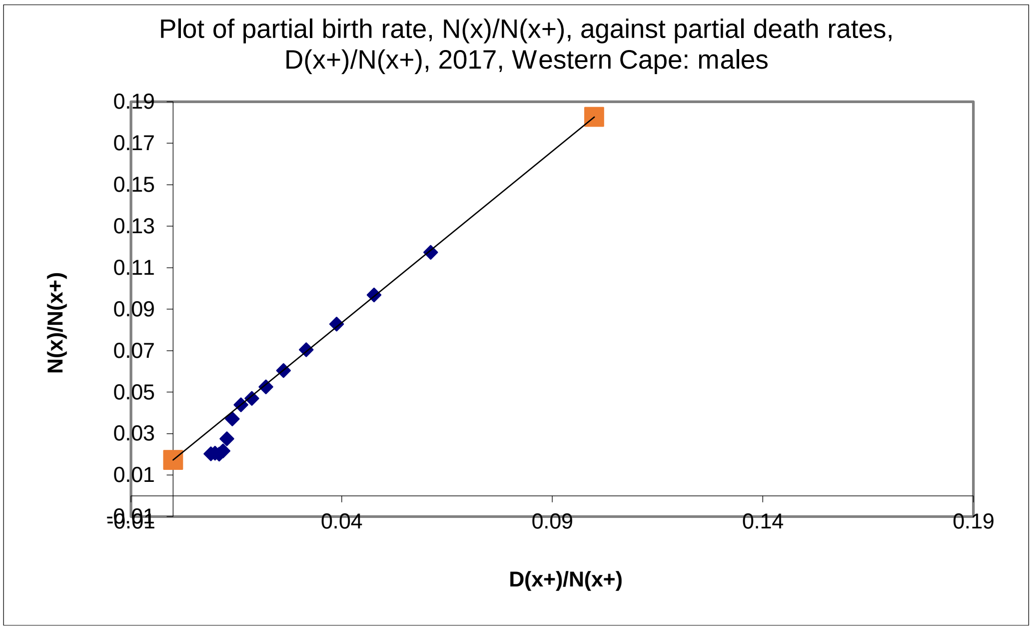
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 17b: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Northern Cape: females



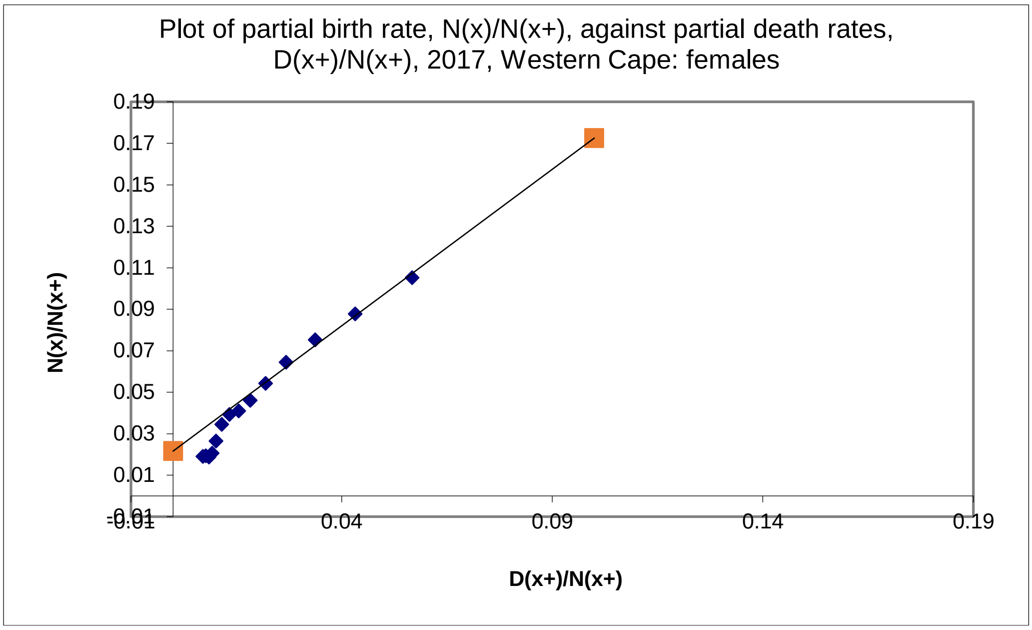
Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 18a: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Western Cape: males



Source: Author's computation from Statistics South Africa's Death Records Files

Appendix 18b: Fitting the Growth Balance Method to Official Figures of Reported Deaths 2017, Western Cape: females



Source: Author's computation from Statistics South Africa's Death Records Files