1. INTRODUCTION

The efforts in evaluating and monitoring the past 2015 Millennium Development Goals (MDGs) has been so crucial for most African countries towards achieving set targets. The post-MDGs era now entails the realisation of the need of reliable data so crucial for developmental planning.

Overall when demographic data generated is of poor quality, untenable outcomes affecting scientific evidence or policies may result, if pitfalls on such data are overlooked or unaddressed for demographic estimation (Potter, 1977). The demography discipline has addressed those challenges by seeking data integrity or quality prior to further demographic assessments. Principles of evaluation, adjustment and transformation have been relevant for such assessment Hill (1990).

In contrary to less flawed demographic data for developed countries, for African countries in the past four decades demographic data has been deemed as either defective or inadequate with respect to its poor quality (Potter, 1977; United Nations, 1983; Hill, 1990; Cohen, 1993; Brass, 1996; Cleland, 1996; Cohen, 1998; Moultrie *et al.*, 2013). Poor quality data, in turn affects the decision-making process in development and policy planning which results in designing inappropriate programme interventions.

The emphasis on core need of having techniques of indirectly estimating fertility and mortality from defective data has resulted in the 1980s being developed as evidenced in the production of Manual X (United Nations, 1983). That notable effort has allowed for extensions or updates of the methods by Moultrie and colleagues (Moultrie et al., 2013) aiming at improving the quality of fertility and mortality estimates. The investigation of potential data quality issues in census data is required as discrepancies in are noted for direct and indirect fertility estimates for most African countries. If data are of sufficient or good quality such discrepancies are void.

Due to incomplete vital registration system (VRS) in most developing countries the census, therefore, remains as the reliable and main source of fertility as well mortality measurement in developing countries (United Nations, 2004). Indeed a census is not an exceptional stand-alone or alternative data source to a VRS or survey but all are indispensable and complementary for demographic measurement.

Whilst the position on quality of demographic data in censuses also surveys has been contested and investigated using various demographic and statistical tools for some Southern African countries such as South Africa (Phillips, 1999; Moultrie and Timæus, 2002), Zimbabwe and Botswana (Blanc and Rutstein, 1994; Thomas and Muvandi, 1994), such scientific enquiry is rare for Swaziland. Despite regular census enumerations in Swaziland fertility data remains under-examined.

The in-depth analysis of Swaziland census data has been limited probably due to paucity of data. Previous 1976 and 1986 actual raw data sets are not in the reach or easily accessible for public use. The articles seeks to examine the suitability of Swaziland 1976, 1986, 1997 and 2007 census data for deriving plausible fertility estimates by bringing to the fore data quality issues when deriving fertility estimates.

As a preliminary step, census data are evaluated on the accuracy and quality of age reporting errors using age and sex ratios, and the Whipple's index. Also employed are the diagnostic tools of the P/F ratios inherent in the relational Gompertz model and the el-Badry correction method to evaluate fertility data. The multiple census data sources allows for consistency checks on age and/or sex distributions and comparisons of fertility data (United Nations, 2004; Joyner *et al.*, 2012; Moultrie *et al.*, 2013) amongst the four censuses of Swaziland. Therefore the purpose is to demonstrate, but not necessarily quantify the possible errors that may arise from estimating fertility using Swaziland census data. This study focuses on consistency checks using age and sex distributions, average parity distributions and age pattern of fertility as basis for evaluating fertility data using the four census data.

Hill (1990: 134) posits that all data sets are defective, and most are deficient-always requiring evaluation, often requiring adjustment…". In the same view, National Research Council (2004) and Schoumaker (2014) highlight that errors in census data are inescapable, but focus should be on knowing their existence and potential sources, quantifying their effects, measurement of errors and minimising errors. The authors recognise that evaluating the quality of data is not piecemeal but tenacious requiring various techniques and researchers' knowledge on fertility issues.

In deriving fertility estimates, the potential errors in data are numerous (Potter, 1977; United Nations, 1983; Brass, 1996; Cleland, 1996; Phillips, 1999; National Research Council, 2004; United Nations, 2004; Joyner *et al.*, 2012; Schoumaker, 2014; Spoorenberg, 2014; Vergauwen *et al.*, 2015).

Errors from age distribution are an issue of concern. Age misreporting mainly emanates from supposed socio-cultural issues of non-importance of exact age, memory lapse or poor education leading to ignorance, carelessness, aversion of some digits and other motives in reporting/recording. Several classic demographic tools such as age ratios, sex ratios and Myers', Whipple' and joint score indices are relied on to evaluate irregularities in age-sex composition (Shryock *et al.*, 1976; Brass, 1996; Spoorenberg, 2007). The United Nations (1983) notes that the effect of age misreporting on fertility is complex, but the overall effect tend to be small.

Also noted , errors (of different types) which may have occurred on a simultaneous basis could lead to a similar effect on fertility (Schoumaker, 2014) or a balance (Shryock *et al.*, 1976; National Research Council, 2004). Brass (1996) cautions the difficulty in proving the effects of some source of errors on fertility being notably different from others. Of value concern is the overall effect of gross or net errors on fertility estimates that has occurred despite the direction, quantity and magnitude of different errors in data (National Research Council, 2004). Thus United Nations (2004) and Moultrie et al.(2013) posit that though data may portray errors on some aspects, it may be possible to come up with robust levels and trends of fertility.

The types, causes and effects of errors on estimates of fertility are highlighted in demographic literature (United Nations, 1983, 2004; Moultrie *et al.*, 2013; Schoumaker, 2014; Vergauwen *et al.*, 2015). A distorted age-sex structure through bias and errors in age-sex data has implications on fertility estimates and projections (Spoorenberg, 2014).

Recent births in the last year reflect current fertility while children ever born (parity) data provide lifetime fertility measures. The quality of data on current and lifetime fertility collected in censuses is also prone to bias and errors. Common quality issues on age-sex and fertility data relate to omission, duplication, misreporting, mistiming or misplacement of birth events, selection bias and nonresponsive/response irregularities due to memory lapse or recall problems and/or negligence

(United Nations, 1983; Hill, 1990; Brass, 1996; Cleland, 1996; United Nations, 2004; Moultrie *et al.*, 2013; Vergauwen *et al.*, 2015).

Omission of births leads to an understatement of fertility and is often caused by exclusion of infant deaths, children adopted away and living elsewhere. The effects of omission on fertility or inclusion of still births on parity is only marginal if correctly accounted and adjusted for using indirect methods. Also the question on recent births excludes the births of dead women prior to the census. The implied assumption is that the childbearing experience of the surviving women is the same as those dead. This selection effect is often small or negligible unless the mortality risk for reproductive women is high. Selection effects may be offset by reporting errors and permits attention in case of exceptionally high mortality (Moultrie et al., 2013; Schoumaker, 2014) due to HIV/AIDS in particular for higher prevalence African countries such as Swaziland.

The death of women in the reproductive lifespan and infants due to HIV/AIDS has negative effect on fertility. Evidence show lower fertility among HIV-infected women than those uninfected (Ntozi, 2002; Lewis *et al.*, 2004; Young, 2007). HIV-uninfected women are predisposed to have a higher childbearing experience than those infected and therefore represented more in age-parity data (Moultrie et al., 2013). The HIV status of women in census data is not collected making it difficult to estimate its impact on fertility.

The possible effects of errors or bias, in magnitude or direction, can be compensated by adjustments using appropriate methods of applications and assumptions in fertility estimation (Hill, 1990; Moultrie et al., 2013). For example, information on lifetime fertility (parities (P)) and current fertility (F) has led to utilisation of a resourceful demographic tool– lifetime/ current fertility (P/F) ratio. This ratio is vital to evaluation of fertility data and estimation of fertility using many indirect methods derived on this principle such as the preferable relational Gompertz model (Moultrie et al., 2013).

Also to mention is that it is difficult to uncover, distinguish or correct all errors in data. For instance, errors that occur through editing and imputation of the data (United Nations, 2004; Moultrie *et al.*, 2013) may prove difficult to investigate if no further documentation on data is provided. In the next section a number of basic demographic tools for consistency checks measures are explained.

2. DATA AND METHODS

The data for this study are based on published raw and aggregated census tabulations on 1976, 1986, 1997 and 2007 censuses undertaken by the Central Statistics Office (CSO) of Swaziland. Published raw data on population distribution by age and sex were used. Tabulated aggregated demographic data collected from census reports were fertility variables on recent births and children ever born. The question on children ever born was asked from women over some minimum age, 12 or 15 years in the censuses.

Consistent with modern census questioning on fertility the four censuses in Swaziland are similar in content. Although raw data for 1976 and 1986 censuses are not accessible, published aggregate data on age, sex and fertility are credible for appraisal of census data quality.

For the available raw data, the 20 per cent sample of 2007 censuses lacks information on missing parities useful for assessing parity distributions, whereas the 1997 census full data set has adequate fertility variables. To maintain consistency on data use, single year and aggregated data were derived from descriptive tables of published census reports for the total population. The methods used to evaluate age-sex and fertility data on the four censuses are explained in the next sections.

2.1 Quality of age-sex data

Classic demographic ratios and indices such as sex ratios, age ratios, Whipple’s index and Myers’ blended index are the several methods used for appraisal of age-sex data for errors in age misreporting and digit preference or avoidance (Shryock *et al.*, 1976; Spoorenberg, 2007; Moultrie *et al.*, 2013). The discussion on methods which follows draws extensively from these authors.

The sex ratio, defined as the number males for every 100 females, is one simple measure of evaluating age-sex data by merely observing its deviation from 100, a point defining equal size of males and females. The overall sex ratio largely depends on the population age distribution. An expected range of deviation from 100 should be accounted for by changes in the population such as migration and mortality. Consistency of sex composition can be verified when the sex ratio in one census is compared to that of the previous census. In most populations the sex ratio at birth (SRB) is expected to be above 100 signifying excess male over female births. The SRB is generally estimated or assumed to be 105 and can be expected to be lower in African populations closer to 103 or 100 in some cases. The sex ratio (SR) for a given single age x is expressed mathematically as:

$$SR = P_x^m \big/ P_x^f \times 100$$

Where P_x^m and P_x^f refers to male and female population at age x , respectively. Moultrie et al. (2013)opined that in the age range 0 to about 45 years a typical sex ratio for developing countries declines gradually with increasing age with exception of excess net migration, especially among young adults. A steep decline occurs at older ages when male mortality is in excess of females.

The age ratio is obtained as a quotient of the population in a particular age group divided by the average population of the two adjacent age groups. The age ratio (AR) is expressed as follows:

$$AR = {}_5P_x \big/ \left(0.5 \times \left({}_5P_{x-5} + {}_5P_{x+5}\right)\right) \times 100 \ ,$$

Where ${}_5P_x$ refers to the population at age x to $x+5$, ${}_5P_{x-5}$ and ${}_5P_{x+5}$ represents the preceding and successive age groups of population. Like the sex ratio at each age group the deviation from 100 implies net age misreporting. This can be expected as selective under-enumeration, over-enumeration or misclassification of age and a combination one or more. A glitch in the age ratio often ignored is that the omission of the central age in the denominator leads to its upward bias.

Both internal consistency (meeting typical patterns on age and or sex distribution) and external consistency (comparison of data across censuses from the same country) are vital in data assessment (Moultrie et al., 2013). Therefore for both age and sex ratios an age range from birth to older ages were assessed with the expectation of an oldest 49 year old women 1976 census would be are around 80 years in the 2007 census.

The Whipple's index is utilised for single year age data to show the extent of heaping on certain ages, usually 0 or 5 in the age range 23 to 62 (Shryock et al., 1976). The Whipple's index (W) is given as:

$$W = 100 \times 5\sum_{x=25,5}^{60} P_x \Big/ \sum_{x=23}^{62} P_x \ ,$$

Where $\sum_{x=23}^{62} P_x$ refers to summation of population in single year completed ages x from 23 to 62 and $\sum_{x=25,5}^{60} P_x$ stands for the summation of population completed single year ages x in multiples of 5 from 25 to 60, that is, for ages with digits ending with 0 and 5. For its range 100 to 500, a value of 100 indicates no heaping and 500 massive heaping. Between the extreme values the quality of data is graded on a scale of accurate, approximate and rough representation.

The 23-62 age range for the Whipple's index was altered to 23-52 to represent women in the reproductive lifespan for each census data under the same linearity assumptions. The digits 0 and 5 in the numerator are distributed evenly or linearly over 5 year ages in the denominator, with the exception of ages lower than 23 and older ages greater than 62 (Shryock et al., 1976; Spoorenberg, 2007) or 52 in the case of this study. A woman aged 49 probable would be able to respond to an age of 50 in a census due to 0 digit preference. According to Spoorenberg (2007) the Whipple's index is that the extent of digit preference is meant for terminal digits 0 and 5. Age heaping at any age other than 0 or 5 may occur which can be detected using the Myers' blended index. The index can be applied to an age range of 10-89 for all terminal digits: 0-9 (Shryock et al., 1976).

Since a shorter age range for women aged 15-49 is considered in this context a Whipple type version of the Myers' index would be considered since it uses the same principles of the Myers' index. Spoorenberg (2007) following the work proposed in 1992 by Noumbissi of modifying the Whipple' index to detect age heaping at age 0 and 5 separately, extended the index to each terminal digit, i, for 0 to 9 and hence the term 'digit-specific modified Whipple's index (W_i). Based on

Spoorenberg (2007) algebraic expressions of W_i, an age range of 21-52 was considered representing women in the reproductive lifespan for each census.

The modification on Spoorenberg equations on W_i for each terminal digit 0 to 9 limited to the age range 21-52 is expressed as follows:

$$W_0 = 5(P_{30} + P_{40} + P_{50})/({}_5P_{28} + {}_5P_{38} + {}_5P_{48});$$

$$W_1 = 5(P_{31} + P_{41})/({}_5P_{29} + {}_5P_{39});$$

$$W_2 = 5(P_{32} + P_{42})/({}_5P_{30} + {}_5P_{40});$$

$$W_3 = 5(P_{23} + P_{33} + P_{43})/({}_5P_{21} + {}_5P_{31} + {}_5P_{41});$$

$$W_4 = 5(P_{24} + P_{34} + P_{44})/({}_5P_{22} + {}_5P_{32} + {}_5P_{42});$$

$$W_5 = 5(P_{25} + P_{35} + P_{45})/({}_5P_{23} + {}_5P_{33} + {}_5P_{43});$$

$$W_6 = 5(P_{26} + P_{36} + P_{46})/({}_5P_{24} + {}_5P_{34} + {}_5P_{44});$$

$$W_7 = 5(P_{27} + P_{37} + P_{47})/({}_5P_{25} + {}_5P_{35} + {}_5P_{45});$$

$$W_8 = 5(P_{28} + P_{38} + P_{48})/({}_5P_{26} + {}_5P_{36} + {}_5P_{46});$$

$$W_9 = 5(P_{29} + P_{39} + P_{49})/({}_5P_{27} + {}_5P_{37} + {}_5P_{47});$$

Where P_x is the population in single year completed ages x and ${}_5P_x$ the population age range from x to $x + 4$. A positive (or negative) deviation above (or below) 1 for W_i reflects digit preference (or aversion) for that respective terminal digit. A value of W_i =1 implies no age heaping. The modifications of W_i are noted by Spoorenberg not suitable for assessing external consistency or temporal comparison. And therefore he proposed a total modified Whipple's index (W_{tot}) as an overall summary index of age reporting as follows:

$$W_{tot} = \sum_{x=0}^{9} |W_i - 1|$$

The summary index indicates no heaping if a value of 0 is obtained and a maximum value of 16 suggests massive heaping or poor quality of age reporting.

2.2 Quality of fertility data

Recent births and children ever born data for women aged 15-49 provide the basis for establishing a number of standard fertility measures and evaluating fertility data in censuses or surveys. Experience from African data on recent births suggests though they are frequently underreported the emerging age pattern of fertility is usually fairly accurate (United Nations, 2004).

Symptoms of omission on parity data according to United Nations (1983) are average parities that fail to increase rapidly enough as age increases. In some specific cases, average parities for women aged 40-44 and 45-49 may actually fall below that for women aged 35-39 even when there is no reason to suppose that fertility has been increasing. Literature suggests the shortcomings in the completeness of reporting of parities may be achieved by using the P/F ratio method of the relational Gompertz model for adjusting upwards the underreporting for births, after correcting for defective parities using the el-Badry technique (United Nations, 1983, 2004; Moultrie *et al.*, 2013).

Generally, with children ever born data, parity of childless women is often incorrectly recorded as if they had an “unknown” or a “not stated” parity. This scenario may increase average parities, especially for younger women and reduce the proportion of childless women. This becomes an issue of concern when proportion of parity in “not stated” category is over 2 per cent for all women in the reproductive lifespan. In such cases the el-Badry correction is employed to detect and correct for distorted parities (United Nations, 1983, 2004; Moultrie *et al.*, 2013; Schoumaker, 2014).

As prior mentioned, the relational Gompertz model is regarded as a robust and the most improved P/F method for preparing fertility estimates (Moultrie et al., 2013). The method provides an effective way of evaluating the extent of age and births misreporting errors in census data as well as correcting or adjusting the fertility schedule accounting for the errors occurred. The spreadsheets “FE_Relational Gompertz” and “FE_elBadry_0” (Moultrie et al., 2013) were used to adjust age-specific fertility rates and parities.

A typical pattern for age-specific fertility rates on recent births from census data is characterised by a right-skewed concave shape showing lowest fertility rates for older ages nearing end of childbearing, lower fertility at the beginning of reproductive lifespan for the youngest age group 15-19. In-between a peak of childbearing is observed especially prior to the age of 30 (Moultrie et al., 2013). Basing on a typical fertility curve a number of demographic fertility models such as the Coale-Trussell and Gompertz models have been derived to fit fertility data (United Nations, 1983).

Using the spreadsheet by Moultrie et al.(2013) for the relational Gompertz model the inputs of reported age specific fertility rates and suitably corrected average parities, using the el-Badry method, are used to generate a corrected fertility schedule which conforms to expected alpha (α) and beta (β) parameter ranges. The relational Gompertz models applies in the range $-0.3 < \alpha < 0.3$ and $0.8 < \beta < 1.25$. The α and β measures age location and spread of fertility schedule, respectively.

The fitting of α and β were done in such as way that accurate reporting is observed when a corresponding set of F-value and P-value points strikingly linearly coincide on the same line. This also implies constant fertility when P/F ratio equals 1 (or is very close to unity in real data). Possible irregularities in data occur if the P/F value diverges from constant fertility. Alternatively this implies a fertility trend- decline or increase in fertility (Brass, 1996; Moultrie et al., 2013)

The consistency checks on fertility data with regard to age-sex distribution, average parities and age-specific fertility rates plausibility or expected fertility patterns are employed to assess the quality of fertility data in census data.

3. RESULTS

As a starting point, the base population data in Figure 1 provide a visual display of assessing age heaping and highlighting error patterns in census data. Overall, the results show an irregular pattern of the age distribution in all the censuses reflecting a non-smooth age reporting or age heaping at ages 0 and 5 and for other terminal digits. Such age heaping seems to have occurred for women aged 15-49 in each census. Another explanation shows the same pattern of age heaping for the women aged

15-49 when following the same cohort from 1976 to 1986, 1997 and 2007 suggesting the population is enumerated satisfactorily. According to Moultrie et al. (2013) a typical population size distribution pattern for developing countries is that which shows a gradual decline with increasing age to which the results conforms . Also in the entire censuses, with the exception of the 1976 census, the number of births at age 0 has been lower than those slightly older showing a decline in fertility which is underway for Swaziland.

Figure 1 about here

Further applications are set out to assess the extent of age misreporting in the four censuses. The summary values of the Whipple's index (W) and the total modified Whipple's index (W_{tot}) for women in the reproductive lifespan are shown in Table 1. The quality of age reporting for women in childbearing has been found to be improving over time as reflected by a decrease in both Whipple's indices over time. The Whipple's index (W), suggests in 1976 and 1986 censuses age data reported were of rough quality. In 1997 and 2007 age reporting improved to approximate accurate and highly accurate, respectively. A similar pattern is observed on the total modified Whipple's index (W_{tot}); a summary index which suggests the lower the values are closer to zero the less the extent of digit preference in age reporting. Thus a value 0.7 indicates almost no age digit preference for the recent 2007 census and somewhat heaping of ages in the 1997 and 1986 censuses, which is higher in the earlier 1976 census. Thus reasonable accuracy on all census data on age seems to have been reported in Swaziland.

Table 1 about here

The Whipple's index confirms age heaping for digits ending with either 0 or 5 in all the censuses except for the 2007 census (values <105 signifying no digit preference).

The pattern of digit preference (or aversion) for each terminal digit 0 to 9 is shown in Figure 2 of the digit-specific modified Whipple's indices (W_i). With the exception of the 2007 census, the finding shows the significant pattern of age preference of 0, 5 and 8 in 1976, 1986 and 1997. Similarly the pattern of age misreporting is observed with the ages ending in either digit 1 or 7 being least reported.

Figure 2 about here

In addition to summary measures observed above employed are ratios vital in evaluation of census data. The irregular patterns of sex ratios (Figure 3) and age ratios (Figure 4) are indicative of errors of age misreporting, undercounting or overcounting in census data.

With the sex ratio it is expected for most populations that male mortality is of little excess than of females as shown in Figure 3 for Swaziland. The sex ratios at births are slightly below 100 in all the censuses indicating the possibility of underreporting of births or ages. The sex ratios at birth were estimated at 95.7, 93.3, 97.5 and 98.0 for the 1976, 1986, 1997 and 2007 censuses, respectively. The sex ratios in the middle ages, especially for ages 20-35, are overly below 100 reflecting either or a combination of excess male mortality due to HIV/AIDS, high emigration of males for labor, or lower sex ratio at birth.

The Figure 4 tends to exhibit an irregular pattern of age ratios in all the censuses for women aged 30-49. This suggests misclassification of ages or probable undercounting for women in the middle to later childbearing years.

Figure 3 about here

Figure 4 about here

Rates in fertility for women aged 15-49 are also employed to detect possible anomalies in current reported fertility data. Figure 5 show the reported and relational Gompertz model adjusted age-specific fertility rates. The findings show underreporting of fertility or age reporting errors in all censuses for reported fertility data. When no adjustments to fertility data are made the age specific fertility rates fairly the same. As indicated in Figure 1 that births were declining, a comparison of the fertility rates between 1976 and 2007 in Figure 5 confirms a decline of fertility occurring in Swaziland in the past three decades.

The results indicate a similar trend of peaked childbearing for women aged 20-29 in 1976, 1986 and 1997 censuses which is characteristic of most African countries. The 2007 census, however, illustrates a somewhat different shape of flattened peaked fertility distribution for ages 20-39. This pattern shows a similarity of fertility behavior amongst the represented women, of which, the explanation needs further investigation. Possibly underreporting of births may have occurred for young women aged 20-29 who are expected to have peaked their childbearing otherwise, older women appears to have increased or just delayed childbearing.

Figure 5 about here

Lifetime fertility data on parities if plotted against age group of women would show an expected overall increasing trend as presented in Figure 6. The reported parities were remedy for distorted parities if the overall per cent of unknown parities was greater than 2, as was obtained for the 1986 and 1997 censuses. Figure 6 reflects the reported parities for these censuses were adjusted slightly. The asymptotic “S” shape indicated for 1976 suggests underreporting of parities by older women or possibly rising fertility. A decrease in average parities over time suggests a fertility decline almost at all ages.

Figure 6 about here

4. DISCUSSION AND CONCLUSION

The study aimed at appraisal of age-sex and fertility data as components of census data used for deriving reasonable fertility estimates. Multiple census data are employed to ascertain the level of consistency in estimates or patterns. In developing countries, age and sex data are much relied on in fertility measurement using indirect techniques of estimation. It is vital that the age-sex structure be reasonably complete and accurate to ensure quality on the resulting estimates of basic demographic indices.

According to Moultrie et al. (2013), the basis of such enquiry looks at dimensions on data of age-sex structure, current fertility and lifetime fertility (or average parity) patterns as employed in this paper. Accordingly, consistency checks on the expected or plausible patterns with regard to the three stated dimensions were done using published data from the 1976, 1986, 1997 and 2007 Swaziland censuses. As a caution or a limitation reported or published data utilised could have been edited or manipulated, but the extent of such manipulation cannot be verified when raw data are unavailable (e.g. 1976 and 1986 censuses).

The population distribution, Myers' index, Whipple's index, age ratios and sex ratios were instrumental in checking for consistency or anomalies in the multiple census data. The assessment of the age and sex distribution for all the four censuses using the above-mentioned demographic tools yielded a number of observations.

The quality of age reporting in the 1976 and 1986 census is of moderate or reasonable quality. In three decades, from 1976 to 2007, the quality of age data in Swaziland improved from rough to highly accurate using the Whipple's indices criteria. Both the Whipple's index and the total modified Whipple's index showed consistency in detecting age preference. The preference for ages ending with digit 0 and 5 including 8 for Swaziland decreased drastically over time. The marked decrease is also seen with digits 1, 3, and 7 which had the highest avoidance. No significant differentials in the age reporting between censuses were evident in the census data.

Overall, a consistent irregular pattern of age ratios and sex ratios in singles years of ages in all four censuses reflects age misreporting often due to understating or overstating of ages. Its effect on fertility is uncertain (United Nations, 1983).

The age ratios suggest age exaggeration or displacement. Swaziland appears to have lower sex ratios at birth (above 90 but less than 100) in all censuses suggesting an undercount of male births if not excess male mortality. This is uncommon in most world population but typical for some African countries (Garenne, 2004; Moultrie et al., 2013).

The lower sex ratios at birth for Swaziland, lower than the average for Africans 103 according to (Garenne, 2004), indicates that data are defective. Affirming this, the underreporting of children is reflected also in the age structure which begins with an "L" shaped pattern or depression for single year ages.

The age distribution in single years of population also confirms age misreporting through age heaping or digit preference. The lesser extent of digit preference for the recent 2007 and 1997 censuses compared to the earlier 1986 and 1976 censuses reflects an improvement in the quality of age reporting in the three decades. This may be linked to possibly many factors such as improvement in the education of the populace or data collection procedures in the context of Swaziland.

Recent births and parity data collected from censuses often are limited or inaccurate requiring the use of corrective demographic techniques (United Nations, 1983). Reported data on the average parities appears to be increasing with women's age as expected in all censuses, although underreporting of births for older women is much poorer in 1976 in particular probably due to lower levels of education attained by women then. Similarly the age pattern of fertility appears to be plausible showing a concave shape as expected with the exception of the 2007 census were a flat topped fertility pattern is observed.

However, applying the relational Gompertz technique, a modified P/F ratio method using the reported seemingly less fault current fertility and parity data shows fertility is underestimated in Swaziland. Thus adjustment demographic methods when applied correctly are imperative in evaluating and adjusting demographic data as supported by Hill (1990). For older women aged 45-49 in all the censuses the reported age specific fertility rates were seemingly higher than those adjusted which reflects faulty age reporting for older women.

Estimates of fertility may be flawed by certain degree of errors in reporting of ages and births. The analysis of results indicates some irregularities in age structure in all the four censuses of Swaziland. The irregularities in the age distribution reflected in the sex ratios reflect net migration for young adults.

The extent of age reporting errors in census data is moderate as evaluated as shown in the several methods applied for the four census data and therefore estimates of fertility from the census data can be derived of reasonable quality. Therefore methods of fertility measurement using the reported parity-fertility data and age-sex population structure can be dependable when best methods and robust assumption on generating fertility estimates are made. However, their usefulness become questionable when age-sex structure and fertility data utilised are defective and incomplete data, of which the study found otherwise.

Actual raw data were not available for the study, except for the 1997 census which was correctly verified with the published census data. The limitation on the published data is that further manipulation and analysis of data was limited. The available raw data requires that data documentation and archiving practice standards should be implemented addressing the processing of data such as on editing

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References

BLANC, A. K. and S. O. RUTSTEIN. 1994. "The Demographic Transition in Southern Africa: Yet Another Look at the Evidence from Botswana and Zimbabwe", *Demography* **31**(2):209-215.

BRASS, W. 1996. "Demographic data analysis in less developed countries: 1946-1996", *Population Studies* **50**(3):451-467.

CLELAND, J. 1996. "Demographic data collection in less developed countries", *Population Studies* **50**(3):433-450.

COHEN, B. 1993. "Fertility levels, differentials, and trends," In Foote, Karen A., Kenneth H. Hill and Linda G. Martin (eds). *Demographic Change in Sub-Saharan Africa*. Washington DC: National Academy Press, pp. 8-67.

COHEN, B. 1998. "The emerging fertility transition in sub-Saharan Africa", *World Development* **26**(8):1431-1461.

GARENNE, M. 2004. "Sex ratios at birth in populations of Eastern and Southern Africa", *Southern African Journal of Demography* **9**(1):91-96.

HILL, K. 1990. "Demographic estimation from deficient or defective data " In Fetter, Bruce (ed). *Demography from scanty evidence : central Africa in the colonial era* Boulder, Colo.: L. Rienner Publishers, pp. 133-142.

JOYNER, K., H. E. PETERS, K. HYNES, A. SIKORA, J. R. TABER and M. S. RENDALL. 2012. "The Quality of Male Fertility Data in Major U.S. Surveys", *Demography* **49**(1):101-124.

LEWIS, J. J., C. RONSMANS, A. EZEH and S. GREGSON. 2004. "The population impact of HIV on fertility in sub-Saharan Africa", *AIDS* **18** (Suppl 2):S35-S43.

MOULTRIE, T., R. E. DORRINGTON, A. HILL, K. HILL, I. TIMÆUS and B. ZABA (eds). 2013. *Tools for Demographic Estimation*. Paris: International Union for the Scientific Study of Population.

MOULTRIE, T. A. and I. M. TIMÆUS (2002) Medical Research Council, Cape Town.

NATIONAL RESEARCH COUNCIL. 2004. *The 2000 Census: Counting Under Adversity. Panel to Review the 2000 Census.* Washington, DC: The National Academies Press.

NTOZI, J. P. M. 2002. "Impact of HIV/AIDS on Fertility in Sub-Saharan Africa", *African Population Studies/Etude de la population africaine* **17**(1):103-124.

PHILLIPS, H. 1999. "Demographic Survey Data in South Africa: An Evaluation of Methodology and Quality", *Southern African Journal of Demography* **7**(1):1-10.

POTTER, J. E. 1977. "Problems in using birth-history analysis to estimate trends in fertility", *Population Studies* **31**(2):335-364.

SCHOUMAKER, B. 2014. *Quality and Consistency of DHS Fertility Estimates, 1990 to 2012*. Rockville, Maryland, USA: ICF International.

SHRYOCK, H. S., J. S. SIEGEL and ASSOCIATES. 1976. *The Methods and Materials of Demography.* New York: Academic Press, Inc.

SPOORENBERG, T. 2007. "Quality of age reporting: extension and application of the modified Whipple's Index", *Population (English edition)* **4**(62):729-741.

SPOORENBERG, T. 2014. "Reverse survival method of fertility estimation: An evaluation", *Demographic Research* **31**(9):217-246.

THOMAS, D. and I. MUVANDI. 1994. "The Demographic Transition in Southern Africa: Reviewing the Evidence from Botswana and Zimbabwe", *Demography* **31**(2):217-227.

UNITED NATIONS. 1983. *Manual X: Indirect techniques for demographic estimation.* New York: United Nations.

UNITED NATIONS. 2004. *Handbook on the Collection of Fertility and Mortality Data*. New York: United Nations, Department of Economic and Social Affairs. http://unstats.un.org/unsd/demographic/standmeth/handbooks/Handbook_Fertility_Mortality.pdf

VERGAUWEN, J., J. WOOD, D. DE WACHTER and K. NEELS. 2015. "Quality of demographic data in GGS Wave 1", *Demographic Research* **32**(24):723-774.

YOUNG, A. 2007. "In sorrow to bring forth children: fertility amidst the plague of HIV", *J Econ Growth* (12):283–327.

Tables

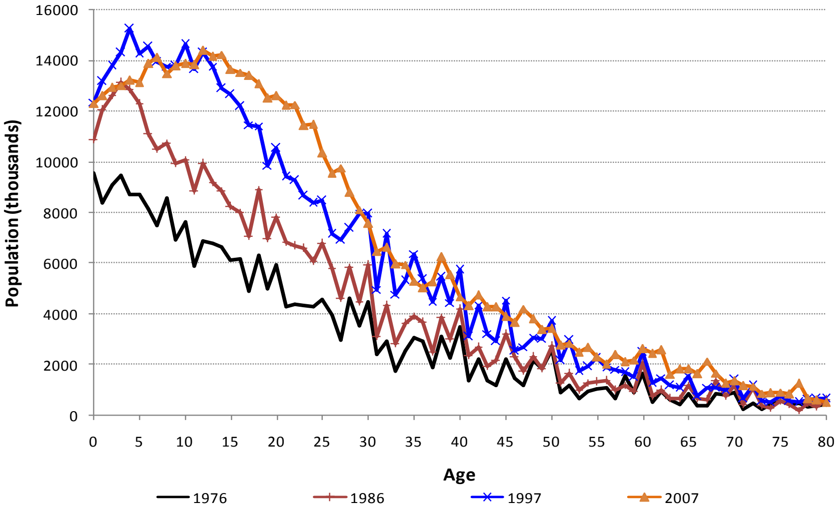
Table 1: The Whipple's index (W), and Total modified Whipple's index (W_{tot}), Swaziland 1976-2007 PHC

Census	W	W_{tot}
1976	129.3	1.62
1986	124.7	1.31
1997	118.4	1.19
2007	98.0	0.37

Source: published raw data from Swaziland Population and Housing Censuses (PHC)

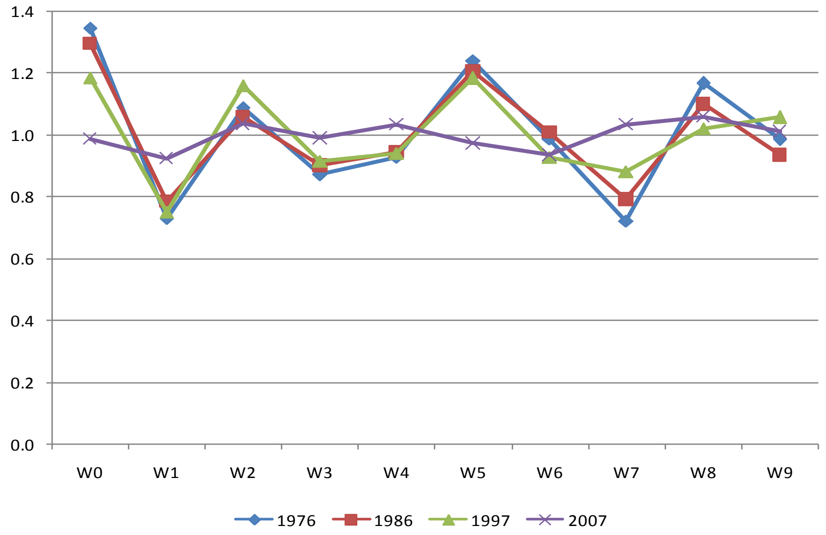
Figures

Figure 1: Age distribution, Swaziland, 1976-2007 PHC



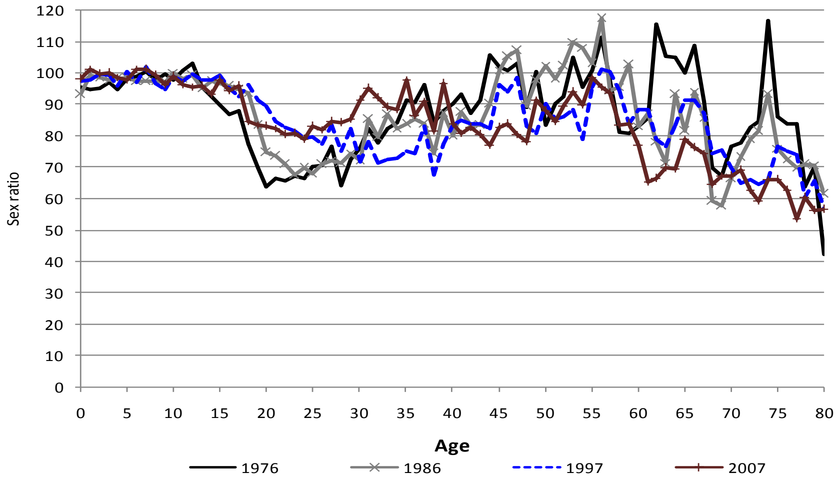
Source: published raw data from Swaziland Population and Housing Censuses (PHC)

Figure 2: Digit-specific modified Whipple's indices (W_i), Swaziland, 1976-2007 PHC



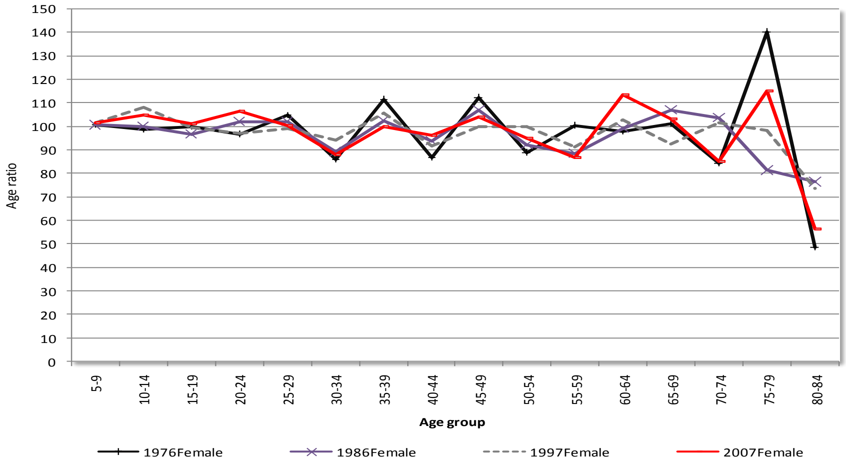
Source: published raw data from Swaziland Population and Housing Censuses (PHC)

Figure 3: Sex ratio Swaziland, 1976-2007 PHC



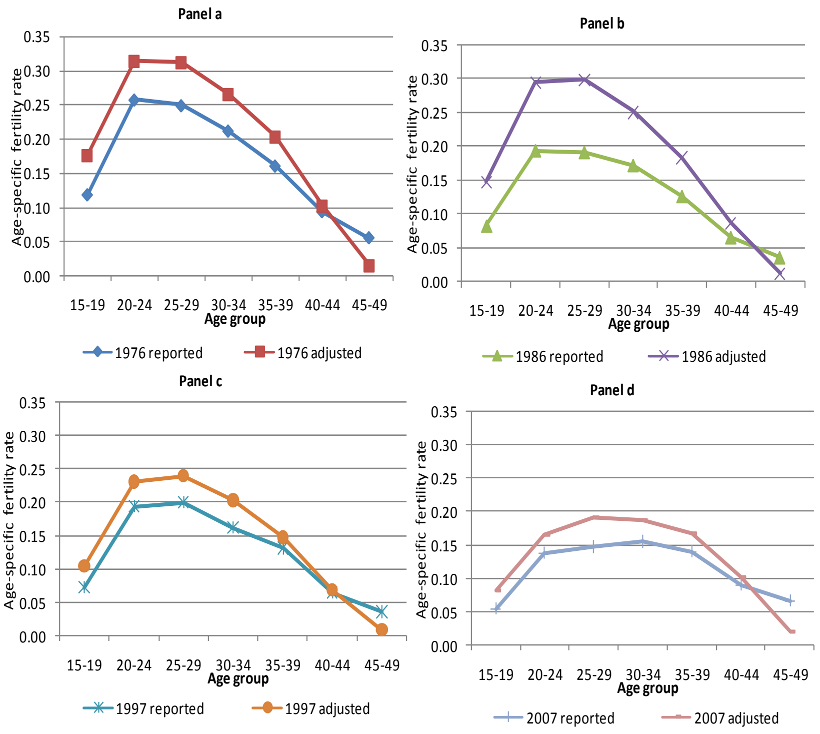
Source: published raw data from Swaziland Population and Housing Censuses (PHC)

Figure 4: Age ratio Swaziland, 1976-2007 PHC



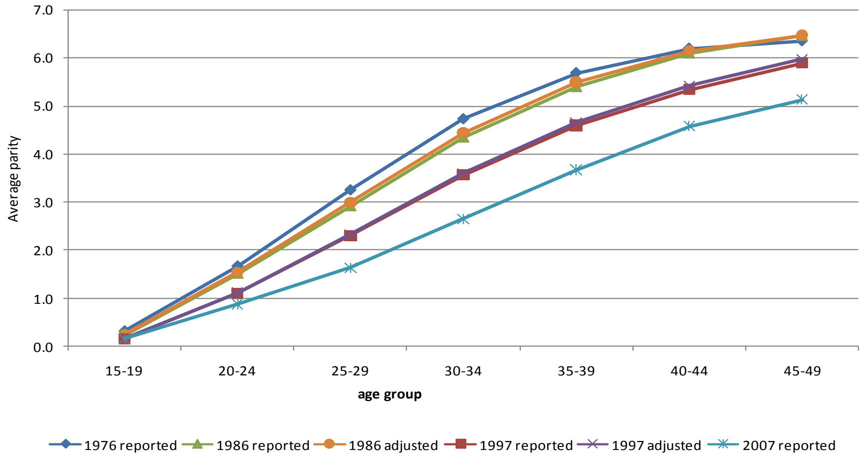
Source: published raw data from Swaziland Population and Housing Censuses (PHC)

Figure 5: Age-specific fertility rates, Swaziland, 1976-2007 PHC



Source: published raw data from Swaziland Population and Housing Censuses (PHC)

Figure 6: Average reported and adjusted parity, Swaziland, 1976-2007 PHC



Source: published raw data from Swaziland Population and Housing Censuses (PHC)