Evaluation of Data Quality of the Botswana 2011 Population and Housing Census

Kenabetsho Bainame [*] ***and Gobopamang Letamo*** [§]

Abstract

The main purpose of this paper is to measure the accuracy of age-sex data collected in the 2011 Population and Housing Census (PHC) at the national level. Demographic analysis tools are employed to evaluate the 2011 PHC data, this is in cognizance of the fact that the vital registration system is incomplete and there was no post-enumeration survey conducted. On the basis of Whipple's Index, Myers indices and Bachi index, the quality of age reporting in the Botswana's 2011 census data is very good, and the data show that there was no serious digit preference. However, the results from the UN Age-Sex Accuracy Index indicate that the 2011 population census age data are not of good quality, with an index score of 21.0. It should be noted that the UN Age-Sex Accuracy Index is unable to separate the inaccuracies and natural changes which raise questions of reliability of the index. The application of the P/F ratio method in the evaluation of 2011 census data shows that ratios are above unity. This pattern implies that there is either an error of underreporting of current fertility relative to lifetime fertility or suggests a declining fertility trend in Botswana in the recent past or the mean parities were over-reported. The first two scenarios are more probable while the last one is highly unlikely given existing evidence. Overall it can be concluded that the census data is of acceptable quality and therefore the 2011 population data could be used to derive credible estimates.

Introduction

A population census is a complex and large-scale operation usually undertaken once in every decade. Because of the complex nature of this undertaking, errors inevitably arise in the collection of census data. Since data from the census inform many important decisions such as monitoring and evaluation policies and programmes, it is imperative that an evaluation of the census data is undertaken to inform the users of the quality of census data. The age and sex data is one of the most fundamental characteristics of population composition. Past changes in fertility, migration and mortality are reflected in the age-sex structure of a population. Conversely, the age-sex structure of a population affects its fertility behaviour, migration, mortality and morbidity levels, labour force participation, and a host of other factors. It is therefore apparent that accurate age-sex data is always essential for analysis of population dynamics.

Data quality assessment provides an evaluation of the overall quality of census data. The results are used to inform users of the reliability of the data and to make improvements for the next census. Quality assessment activities take place throughout the census process, beginning prior to data collection and ending after dissemination. No matter how well designed a census is, the data generated from it will always contain some errors. Errors can occur at any stage of the census process. In order to assess the usefulness of the census data, users of the census data should be aware of the types of errors that can occur in the data. United States (US) Bureau of the Census (1985) argues that census figures that are subject to error are still valuable if the limitations of the data are understood by the users, and if the errors do not adversely affect the major uses of the data. Therefore it is imperative that errors affecting the 2011 population and housing census are evaluated and appreciated before delving into the analysis of the data. Information on the size, distribution and characteristics of a country's population

[*] Kenabetsho Bainame, Department of Population Studies, University of Botswana. Email: bainamek@gmail.com

[§] Gobopamang Letamo, Department of Population Studies, University of Botswana. Email: gobopamangletamo@gmail.com

is essential for describing and assessing its economic, social and demographic circumstances and for developing sound policies and programmes aimed at fostering the welfare of a country and its population (United Nations 1998). By programmes we refer t such fields as education and literacy, employment and manpower, family planning, housing, maternal and child health, rural development, transportation and highway planning, urbanisation and welfare.

The main types of error affecting census data are: coverage errors, non-response errors, response errors and processing errors. The US Bureau of the Census (1985:3) defines coverage error as 'the error in the count of persons or housing units resulting from cases having been "missed" during census enumeration or counted erroneously either through duplication or erroneous inclusion'. Coverage errors occur when dwellings and/or individuals are missed, incorrectly included or counted more than once. It is not unusual in most of the developing countries to report undercounts in censuses mainly because some areas are inaccessible or some population groups are hard to cover completely.

Non-response errors occur when some or all information about particular individuals, households or dwellings is not provided. Response errors occur when a question is misunderstood or a characteristic is misreported by the respondent, or by the census enumerator. Processing errors may occur at any stage of processing. Processing errors include keying errors that can be made at data capture during coding operations, when written responses are transformed into numerical codes, and during imputation, when valid (but not necessarily correct) values are inserted into a record to replace missing or invalid data.

Data quality assessment can be done for a variety of reasons, including guiding improvements in future censuses and surveys, assisting census data users in interpreting the results, and adjusting census results (US Bureau of the Census 1985). The main purpose of this paper is to measure the accuracy of age-sex data collected in the 2011 PHC at the national level.

Methodology

Demographic analysts typically make extensive use of sex and age ratios in assessing data quality in censuses and surveys. The reason for this is that these ratios 'behave' in a rather predictable manner in the absence of catastrophic events such as wars, serious famines or epidemics, and large-scale flows of international migrants. Even for populations affected by these factors, the resulting effects on the age-sex distributions can usually be anticipated and interpreted accordingly (US Bureau of the Census 1985). The following evaluation methods of population census data through demographic analysis were used: 1) graphical analysis of age-sex distribution (age-sex pyramid); 2) summary indices such as Whipple's Index; Myers' Index, Bachi's Index and UN Age-Sex Accuracy Index and other demographic methods specific to fertility, migration and mortality.

Fertility Data

In developing countries complete reporting of vital events remains a challenge. Therefore, demographic parameters such as the TFR are estimated from household surveys or census data. Direct estimation of fertility levels from survey or census data from developing countries is often impossible because data obtained from questions on current fertility (i.e. births in the last 12 months before enumeration date) are usually fraught with problems. Generally, these data tend to yield lower age-specific fertility rates (ASFR), especially among younger women (Feeney 1998). This consequently leads to lower estimates of TFR than is the case. The problem is addressed by employing indirect estimation techniques that involve applying some multipliers (derived from parity data), to adjust the observed ASFRs to arrive at a more reliable approximation of TFR (United Nations 1983).

Migration Data

The 2011 PHC asked three types of questions which relate to internal migration and these were: place of birth, place of residence at some specified time in the past one or five year(s) ago, and current residence. According to the United Nations (1955), the data resulting from these types of questions are very useful for analysis of internal population movements even though they are subject to weaknesses. Therefore, an evaluation of migration varies with the forms in which the relevant census questions are asked and the supplementary data required to test migration data. For the 2011 PHC, despite the availability of information on the three types of migration questions, there is no sufficient information to apply the test based on the components of the balancing equation. The reason for this is that the data on vital events collected by the vital registration system is far from being complete to allow for such computations.

Mortality Data

The 2011 PHC collected data on the age distribution of deaths and that of the population. These are useful for the evaluation of the completeness of registration of deaths using the Brass Growth Balance Method or Preston and Coale method. While these methods have been widely used in developing countries, especially when the assumptions under the model hold, the recent decline in fertility in Botswana has meant their application can no longer be useful given that the estimates are sensitive to changes in fertility (Fosu 2001). However, alternative methods that use similar information for closed population have been proposed. These methods relax the assumption of stability (Hill 1987).

While Botswana has been able to conduct decennial censuses since the 1970s, the data on the registration of deaths in the intercensal period has been incomplete thereby making the application of the methods inadequate.

Results

The results are presented in two sections namely general methods for evaluating census data and those specific to the three demographic processes of fertility, migration and mortality.

Graphical Analysis of Age-Sex Distribution

One expects that some findings from graphic evaluation methods will be presented here, or graphic presentation showing the extent of distortion in the age-sex structure. It will be interesting to see if there are certain ages/age ranges that are prone to preference or avoidance.

Summary Indices

The first step is to examine the 2011 census data for age reporting errors. Various methods have been developed to assess deficiencies in age data. These include the Whipple's index, the Myers' blended index, Bachi index and the United Nation's age-sex accuracy index. The Whipple's and Myers' indexes perform analysis of digit preference in reported single year age distributions whilst the UN age-sex accuracy index provides a picture about the accuracy of age data by combining analysis of age ratios and analysis of sex ratios (Shryock *et al* 1976 and Arriaga 1994).

Whipple's Index

Whipple's index assumes uniform distribution of population in a five-year range and aims to detect heaping on terminal digits '0' and '5' in the range from 23 to 62 years. The index varies between 100 representing no preference for '0' or '5' and 500 indicating that only ages ending in '0' and '5' were reported (Shryock and Siegel 1976). The choice of 23 and 62 as the limits of the age band to be examined in the classic Whipple's index calculation is arbitrary but has been found to be most suitable for the practical purpose of measuring age heaping in general in a population of all ages (UN 1995).

The United Nations recommended a standard for measuring age heaping as described in Table 1 below.

Table 1: The UN Recommendation for Measuring Age Heaping as Identified by Whipple's Index

Whipple's Index	**Quality of data**	**Deviation from**
‹105	Very accurate	5%
105-110	Relatively Accurate	5-9.99%
110-125	Ok	10-24.9%
125-175	Bad	25-74.99%
› 175	Very Bad	≥75%

Source: Statistics Botswana (2011)

On the basis of Whipple's Index the quality of age reporting in the Botswana's 2011 census data is very good, with Whipple's Index of 101 for males, 100 for females and 101 for both sexes. These data show that there was no digit preference for '0' or '5'.

Myers' Blended Index

The Myers' Index was developed to detect preference for all terminal digits from 0 to 9. The method yields a reference index for each terminal digit as well as a summary index of preference for terminal digits. The theoretical range of Myers' Blended Index is from 0 to 90. An index of 0 represents no heaping and an index of 90 represents a heaping of all reported ages at a single digit (Shryock and Siegel 1976).

Myers' index was computed to detect preference for certain terminal digits. Myers indices show that there was no digit preference in the 2011 census data. Myers Indices of 2.3 for males and females separately and 2.2 for both sexes combined were reported for the 2011 census data. The indices show no digit preference.

Bachi Index

The Bachi index as an indicator of the general extent of heaping is similar to Myers' index. It involves applying the Whipple method repeatedly to determine the extent of preference for each terminal digit. Like the Myers index the Bachi index is equal to the sum of the positive deviations from 10 percent. It considers the population between 23 and 72 years. The theoretical range of the Bachi index is 0 to 180, where the interpretation of 0 is no age heaping, and the interpretation of 180 is all ages reported at a single digit. Positive values represent a preference for a digit, and negative values represent avoidance of a digit. Bachi index of 1.1 for males and 1.3 for females and 1.2 for both sexes combined were reported for the 2011 census data. The indices show no digit preference nor do they represent avoidance of certain digits.

Overall, Table 2 below presents a summary of the computed indices on age heaping. In order to get a broad picture about the magnitude of age preference, Whipple's, Myers and the Bachi indices were computed separately for males and females and for both sexes combined (see Table 2). The respective values are 1.0, 2.2, and 1.2 for both sexes. All three indices support the argument that age reporting was accurate.

Table 2: Summary Indices of Age Misreporting, Botswana 2011 Census

Index	**Male**	**Female**	**Both Sexes**
Whipple's	1.01	1.00	1.01
Myers	2.3	2.3	2.2
Bachi	1.1	1.3	1.2

Source: Statistics Botswana (2011)

United Nations Age-Sex Accuracy Index

Age ratio analysis (United Nations 1952) using population data for 5-year age groups is used to detect age misreporting in populations where fertility has not fluctuated greatly during the past and where international migration has not been significant. Calculations entail dividing the population in a specific 5-year age group by the average population of the two adjacent 5-year age groups, times 100. The larger the fluctuations of these ratios, the larger their departure from 100, the greater the probability of errors in the data. Sex ratios are simply calculated by dividing the male population by the female population in a given age or age group, times 100. For most middle age groups, and depending on the level of sex-specific migration in a population, the larger the departure from 100, the larger the possibility for errors in the data. For the youngest ages 0 or 0-4 the sex ratio tends to range between 103 and 105 due to biological factors which result in an excess of male births.

For some countries, sex ratios for births occurring in the latter half of the twentieth century have dramatically increased, to levels above 112 for example, as a result of sex-selective abortions where some parents have a preference for male children over female children. For the oldest age groups, the number of females tends to exceed males. However, there are exceptions to this trend as well largely in societies that favour males. Joint age- and sex-indices – the sex-ratio score, the age-ratio score, and the age-sex accuracy index – developed by the United Nations (1952 and 1955) are used as summary measures of the age and sex ratios. The accuracy index is the sum of the male and female age ratio scores plus three times the sex ratio score all calculated using data for ages 0-14 through 65-69.

The method was selected because it uses age data (in 5-year age groups) for both sexes and consequently provides an overall evaluation of age and sex data in a population. Although our interest is on the quality of age data for women in reproductive ages, it is an added advantage to know the overall quality of the data in the 2011 census. The index uses sex ratios and age ratio scores (for both sexes) to assign a composite score that shows the relative ranking of the quality of a given age-sex population distribution (Shryock *et al* 1976 and Arriaga 1994). The UN classifies population age-sex structures into three categories: 1) *accurate* – if the index score is less than 20; 2) *inaccurate* – if the score is between 20 and 40; and 3) *highly inaccurate* – if the score is above 40. The results from the UN Age-Sex Accuracy Index indicate that the 2011 population census age data are not of good quality, with an index score of 21.0. However, this figure is slightly above the cut-off point of 20 score which reflects the data are inaccurate. It should be noted that when interpreting the UN index care should be taken to examine any changes in age-sex composition arising out of demographic components, as the index is unable to separate the inaccuracies and natural changes.

Shryock and Siegel (1976) have observed that the main limitations of the index is that it fails to take into account the expected decline in the sex ratio with increasing age and of real irregularities in age distribution due to migration, war and epidemics as well as normal fluctuations in births and deaths. Another limitation they observed is that the index uses a definition of an age ratio which omits the central age group which therefore has an upward bias. It should also be noted that considerable weight is given to the sex ratio component in the formula (Shryock and Siegel 1976). As a consequence of the imbalances in the sex ratio in favour of females due to high mortality among males the joint score for Botswana appear to be affected by these differentials.

Fertility Data

The reliability of age specific fertility rates (ASFRs) and consequently TFR estimates obtained from Brass-type questions depends on the quality of reported parities as well as the quality of the data on births in the last 12 months before survey. However, the accuracy of these data also depends on the quality of age reporting among women of reproductive ages (Arriaga 1994; Retherford and Mirza 1982).

Quality of parity Data

The paper follows a three-step approach in evaluating the quality of the parity data collected in the 2011 census. In the case of age data, the paper firstly examines the quality of the data by examining their internal consistency. This approach involves checking the distribution of women by reported children ever born (CEB), looking for implausible figures in the reporting of children ever born. Specifically, the paper checks for the reported numbers of CEB that are physiologically not possible or not consistent with what is known about fertility behaviour in Botswana.

The second assessment of the CEB data involves an evaluation of the pattern of average parities by age of mother and consistency checks in the reported average parities in 2011 census and other datasets, to determine whether cohorts of women reported consistent numbers of CEB. This type of evaluation is, however, suited for the terminal ages of the reproductive life span because less childbearing occurs in those ages. The final assessment employs the diagnostic properties of the P/F (Parity/Fertility) ratio method (Brass *et al* 1968) to evaluate the accuracy of parity data in relation to current fertility data in the 2011 census.

Distribution of women by age and parity

Table 3 shows the distribution by age group and reported CEB of all women in the childbearing ages. The overall table shows that the 2011 parity data are consistent with the expected trend which may imply that data are of good quality. For instance, as expected the proportion of childless women decreases with age. The percentage of childless women aged 45-49 is 6.4 percent which may be a reflection of the underlying levels of primary sterility and voluntary childlessness (Moultrie *at al* 2013). Moultrie *et al* (2013) argue that if the percentage had been higher than 10 percent it would have to be subjected to further investigation. Table 3 also shows evidence of suspicious age-specific reporting of CEB. For instance, some women in the age group 15-19 reported up to 4 children. Although these parities are possible with multiple births, they are highly unlikely.

Table 3: Distribution of women of reproductive ages by parity and age, Census 2011

Age group	Total Children Ever Born (CEB)											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**	**Total**
15- 19	59724	135	3	1	3	0	0	1	0	0	0	59867
20 - 24	96972	7529	1133	204	56	29	2	1	0	0	1	105928
25 - 29	52474	32728	13081	3615	877	202	69	30	15	8	2	103101
30 - 34	26028	35501	26392	12038	4531	1490	436	142	72	25	3	106658
35 - 39	11498	20805	23858	15862	7937	3531	1553	602	231	82	67	86027
40 - 44	5884	10824	16671	14047	9043	5116	2712	1344	640	284	219	66784
45 - 49	3245	5720	9966	10396	8198	5354	3341	2017	1150	583	560	50530
Total	257980	116797	97808	64175	38265	21462	12279	6901	3839	1893	1077	623275

Source: Statistics Botswana (2011)

Consistency check of average parities in 2011 census

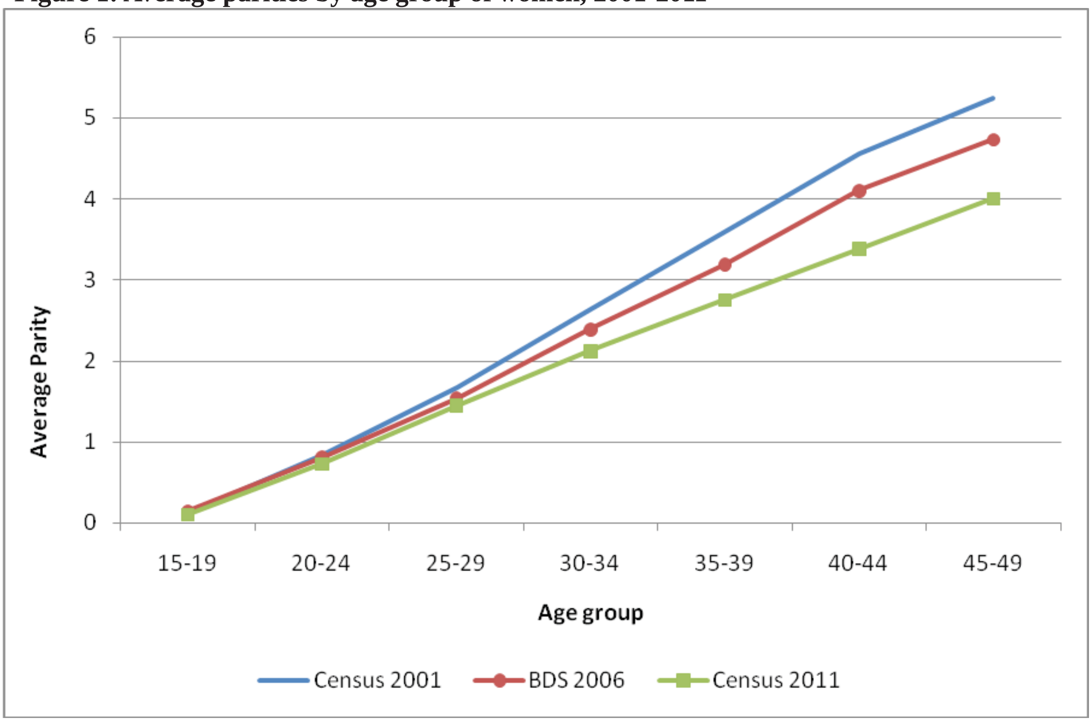
This part of the evaluation involves an assessment of consistency in the reported average parities to ascertain whether cohorts of women reported consistent numbers of CEB over time. It requires that the census data are compared with data from other sources and as earlier mentioned is suited for the terminal ages of the reproductive life span because less child bearing occurs in those ages. Figure 1 below compares the average parities by age group of women in reproductive ages in the census with corresponding average parities in the 2006 Botswana Demographic Survey (BDS) and 2001 population census.

Figure 1 also shows that the average parities from the 2011 are in the expected direction when evaluated in concert with what was observed in the 2006 BDS and 2001 population and housing census.

As expected when the data are of good quality all the three data sources show average parities that increase rapidly with age. In addition, the 2011 data are consistent with the 2006 BDS and 2001 population data sources when using parity of cohorts of women over 2006 and 2011. This trend is commensurate with what is known about fertility trends in Botswana.

Furthermore, the average parity (4.0) of women in the age group 45-49 years is greater than the estimated TFR (2.9) for the 2011 PHC suggesting that fertility has been falling. To ensure that both measures were plausible the Gompertz relational model was used to examine the fertility and parity distributions and their implied relationship. Gompertz relational model indicated that the *P* ***and*** *F* lines converge in the age range 25-34 and thereafter diverge. Assuming the absence of errors by older women in reporting lifetime fertility and errors associated with women less than 20 years, the implied relationship would suggest that there have been substantial declines in fertility in the recent past.

Figure 1: Average parities by age group of women, 2001-2011



Source: 2006 Botswana Demographic Survey; Republic of Botswana (2001) and Statistics Botswana (2011)

Patterns of the P/F ratios observed in the 2011

In addition to it being a technique for estimating TFR the P/F ratio method can also be employed as a diagnostic tool in the evaluation of fertility data obtained in a survey or census (Brass 1968; Chahnazarian 1993; Rutenberg and Diamond 1993; Hobcraft, Goldman and Chidambaram 1982; Trussell and Hill 1980). The method assumes that fertility has been constant in recent years, and errors in the data on current births are not correlated with the age of the mother. In the application of the method mean parity equivalents ($\mathbf{F}_{is}$) are estimated and compared with reported mean parities ($\mathbf{P}_{is}$). The P/F ratios by age serve as indicators of the consistency and accuracy of the two sets of data.

The application of the P/F ratio method in the evaluation of 2011 census data shows that ratios are above unity, ranging from 1.10 to 1.39 (see Table 4). This pattern implies three scenarios. The first is that there is an error of underreporting of current fertility relative to lifetime fertility. Secondly, that pattern suggests a declining fertility trend in Botswana in the recent past. Finally, the pattern may imply that mean parities were over-reported. The first two scenarios are more probable while the last one is highly unlikely given existing evidence.

Table 4: Trussell P/F Ratio Technique, Botswana 2011

Age	Reported ASFR (f_i)	Average CEB (P_i)	Cumulative fertility Phi (i) ($5*f_i$)	F(i)	P/F ratio
15-19	0.039	0.102	0.195	0.080	1.279
20-24	0.138	0.728	0.883	0.595	1.223
25-29	0.137	1.448	1.567	1.299	1.115
30-34	0.117	2.120	2.150	1.926	1.100
35-39	0.090	2.751	2.598	2.433	1.131
40-44	0.045	3.384	2.821	2.735	1.237
45-49	0.014	4.002	2.893	2.877	1.391
Total	2.893				

Source: Statistics Botswana (2011)

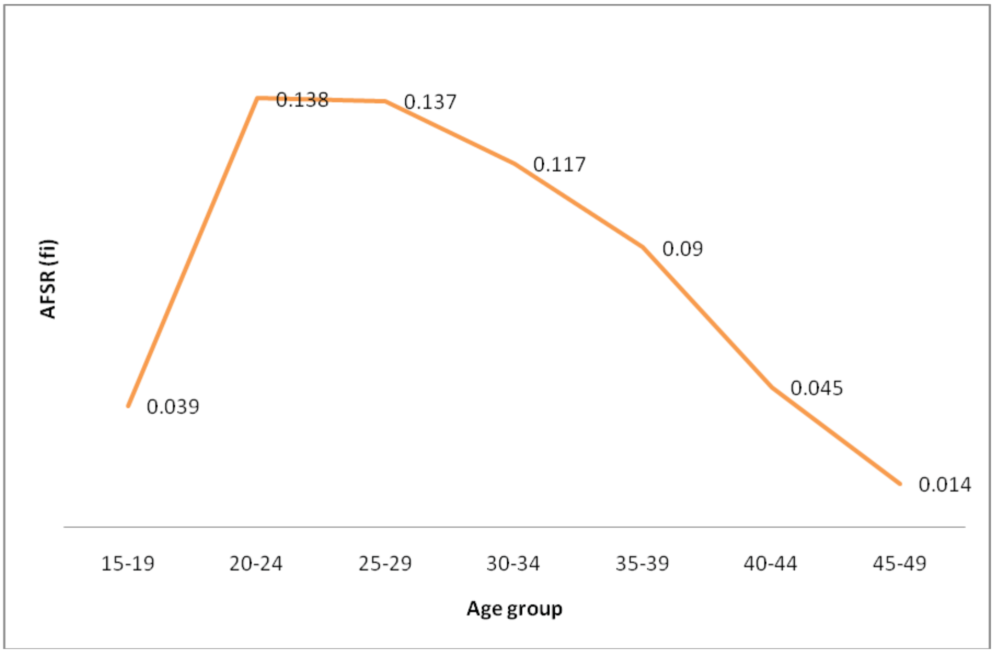
Quality of Data on Births in the Last 12 Months Before Enumeration

Women aged between 12 to 49 years were asked to provide the number of children born alive since Independence Day 2010. This approach sought to address the known problem that women (especially younger ones) tend to underreport births when responding to the question on births during the 12 months prior to a survey/census. This section of the paper briefly evaluates the 2011 census data, focusing on the observed patterns of ASFRs. It uses the 12-month period encompassed by 30 September 2010 (Independence Day) and 30 September 2011 (Independence Day) as reference. Accordingly, all births that occurred during the reference period are used to calculate ASFRs and the TFR.

The observed ASFRs

Figure 2 below demonstrates the pattern of the ASFRs obtained from the data in the last 12 months which looks plausible and suggests that the 2011 population data could be used to derive credible fertility estimates. The graph shows the ASFRs that are consistent with what is known about fertility behaviour of Botswana's population.

Figure 2: Observed age specific fertility rates, Botswana 2011



Source: Statistics Botswana (2011)

Conclusion on the assessment of fertility data

In light of the preceding evaluation of the quality of different aspects of fertility data collected in the 2011 PHC, the following conclusions were made:

- The data assessment methods exhibit that the Botswana 2011 census data are of good quality and this evidence was obtained from the Whipple's, Myers and Bachi indices. However, the UN Age-Sex Accuracy Index shows that the quality of age data is questionable given that the score is 21, a figure which is slightly above the cut-off point of 20 score reflecting good quality data as per the UN Age-Sex Accuracy Index. Note that the index is unable to separate the inaccuracies and natural changes which raise questions of reliability of the index. One of the reasons the age-sex accuracy index is slightly high could also be explained by the skewed distribution of the sex ratio in the country which favours females.
- The shape of the current fertility schedule obtained in the 2011 census suggests that the data are of good quality.

Conclusion

The purpose of this paper was to assess the quality of the 2011 PHC data. Using a variety of data quality assessment methods it can be concluded that the census data is of acceptable quality. All the three age-sex data indices, namely the Whipple's, Myers and Bachi indices showed that the 2011 census data is of good quality. All data consistency checks (distribution of women by age and parity, average parities, Trussle P/F ratio technique, and the pattern of age-specific fertility rates) also indicated that the 2011 census data is good quality.

The only indicator which appear to suggest that the 2011 data may be of questionable quality is the age-sex accuracy index which itself is unable to separate the inaccuracies and natural changes which raise questions of reliability of the index. It is well known in Botswana that sex ratio favours females. As a consequence of the imbalances in the sex ratio in favour of females due high mortality among males, the joint score for Botswana appears to be affected by these differentials, resulting in a slightly high age-sex accuracy index.

The application of the P/F ratio method in the evaluation of 2011 census data shows that the ratios are above unity. It, therefore, has to be agreed that the P/F ratio provides insights into the nature and timing of a decline in fertility, as well as problems with the quality of the data (Moultrie *et al* 2013). The data quality assessment performed that the P/F ratios are close to unit for age groups less than 25 years followed by a series of low P/F ratios, and eventually by higher P/F ratios which suggest that what appears to be underreporting of current fertility relative to lifetime fertility is in all likelihood a reflection of declining fertility in the recent past.

On the balance of things, the authors are convinced by the evidence presented earlier that the 2011 census data of Botswana are reliable. All methods of assessing data quality suggest the data are of good quality because the estimates are within the expected range.

References

Arriaga, EE 1994. Population Analysis with Microcomputers. Volume I. Presentation of Techniques. New York: Bureau of the Census, UNFPA and USAID.

Brass, W 1996. 'Demographic Data Analysis in Less Developed Countries. Population Studies, vol. 50 (3), pp.451–467.

Dorrington, R, Timæus, IM, Moultrie, T and Nannan, N 2004. 'Provincial Fertility and Mortality in South Africa'. Southern African Journal of Demography, vol. 9 (2), pp.27-57.

Feeney, G 1998. A New Interpretation of Brass' P/F Ratio Method Applicable When Fertility is Declining. www.gfeeney.com, accessed 30 August 2008.

Fosu, GB 2001. 'Evaluation of Population Census Data Through Demographic Analysis', http://unstats.un.org/unsd/demographic/meetings/egm/symposium2001/docs/symposium_11.htm#_Toc7406238, accessed on 7 March 2014.

Hill, K 1987. 'Estimating Census and Death Registration Completeness', http://unstats.un.org/unsd/vitalstatkb/Attachment371.aspx, accessed on 7 March 2014.

Kalipeni, E 1995. 'The Fertility Transition in Africa', Geographical Review, vol. 85 (3), pp.286–300.

Lin, JY 2012. 'Youth Bulge: Demographic Dividend or a Demographic Bomb in Developing Countries? Let's Talk Development'. The World Bank. http://blogs.worldbank.org/developmenttalk/youth-bulge-a-demographic-dividend-or-a-demographic-bomb-in-developing-countries. Accessed on 24 July 2014.

Moultrie, TA, Dorrington, RE Hill, AG Hill, K Timæus, IM and Zaba, B (eds) 2013. Tools for Demographic Estimation. Paris: International Union for the Scientific Study of

Population. www.demographicestimation.iussp.org: Accessed on 24 July 2014.

Paget, J, and Timæus, IM 1994. 'A Relational Gompertz Model of Male fertility: Development and Assessment'. Population Studies, vol. 48 (2), pp.330–340.

Republic of Botswana 2006. Botswana Demographic Survey, 2006. Gaborone: Government Printer.

Republic of Botswana 2001. Population and Housing Census, 2001. Gaborone: Government Printer.

Retherford, RD and Mirza, GM 1982. 'Evidence of Age Exaggeration in Demographic Estimates for Pakistan', Population Studies, vol. 36 (2), pp.257–70.

Shryock, H Siegel, JS and Associates 1976. The Methods and Materials in Demography. San Diego: Academic Press.

Statistics Botswana 2011. Population and Housing Census, 2011. Gaborone: Statistics Botswana.

Trussell, TJ and Hill, K 1980. 'Fertility and Mortality Estimation from the Panama Retrospective Demographic Survey, 1976', Population Studies, 34(3): 551-563.

Udjo, EO 2009. 'Trends in the Age Pattern of Fertility, 1995-2005, in the Context of the Child Support

Grant in South Africa', Development Southern Africa, vol. 26 (2), pp.289-299.

Udjo, EO 2005. 'Fertility Levels, Differentials, and Trends', in Zuberi, Sibanda and Udjo (eds), The Demography of South Africa. New York: ME Sharpe.

United Nations 1983. Manual X: Indirect Techniques for Demographic Estimation. New York: Department of International Economic and Social Affairs, United Nations.

United States Bureau of the Census 1985. Evaluating Censuses of Population and Housing, Statistical Training Document, ISP-TR-5, Washington DC: United States Bureau of the Census.