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South Africa's Uncertain Demographic Present and Future

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Contents

Abstract

South Africa faces tremendous demographic challenges, mostly related to HIV/AIDS. Any projection is made even more difficult through significant disagreements over current population size, age structure, fertility and mortality levels. This paper expands methods of expert-based probabilistic population projections to include uncertainty distributions about the current demographic conditions. The result is a probabilistic distribution of future population trends in South Africa combining uncertainty about present starting conditions and future rates. For 2030 the total population of South Africa is projected at 54 million (median) with the 95% uncertainty interval ranging from 36 to 74 million.

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Introduction

After the end of apartheid, South Africa finds itself in a situation with mostly unsatisfactory statistical information for the large majority of its population. There is no consistent historical information and the only complete post-apartheid census in 1996 gave rise to great controversy even about the approximate size of the total population. Different institutions and individuals came up with greatly differing census adjustments which also imply quite different age structures for the population. The UN (1999) bases their projections on a population of 38.1 million for 1996, whereas the Development Bank of Southern Africa (DBSA 1996) assumes 44 million for 1996. This is a difference of 6 million or 16% of the UN estimate.

Given all these uncertainties some demographers may question the feasibility of any kind of population projection for South Africa. Yet such projections are needed for planning purposes, and under conditions of expected dramatic demographic changes, they are even more vital than under more stable, better documented and better predictable conditions. It is because of this need for forecasts that the United Nations, the World Bank and the US Census Bureau produce population projections even for countries that still have more uncertain statistical information than South Africa. Demographers should not shy away from trying to provide the best possible information about the future in the cases where this information is most urgently needed for planning. Such efforts, however, do require a rethinking of the way demographers deal with uncertainty. The standard practice of publishing point estimates for the starting conditions without information about its uncertainty, and then only giving three variants of non-stated probability that are based on different fertility assumptions but identical mortality and migration paths, is clearly inappropriate under such conditions.

Alternative Ways to Deal with Demographic Uncertainty

To be uncertain about the exact size of a population or the current level of fertility, mortality and migration is nothing new for demographers. Almost all empirical information, be it from censuses, vital registration or surveys is imperfect, but the degree of imperfection varies significantly from one setting to another. Whenever the degree of imperfection of the given empirical information has been considered intolerable as a basis for analysis and interpretation, demographers tended to have two alternative strategies: either go out to the field and collect new information or use various kinds of statistical techniques to improve the given data. Sometimes both methods are combined, but the goal has typically been the same: to come up with one point estimate that should be as close as possible to the real world. In international comparisons then these point estimates typically enter tables where, e.g., the highly reliable estimate for life expectancy derived from the Finnish population register stands next to the estimate for Mozambique, where hardly anything is known about current mortality conditions, especially in the face of unknown HIV prevalence. Typically the user of such tables is not given an indication about differential uncertainties surrounding these point estimates. But even if the researchers working with the data are painfully aware of the uncertainty of a given point estimate, they mostly see no other choice than basing their projections and other analysis on this uncertain point estimate of demographic conditions at a given time. Unlike in some other disciplines, there is no tradition in demography to process fuzzy information and somehow maintain information about the uncertainty of the given estimates in subsequent steps of analysis. In this paper we will propose a method to do so by expanding methods of probabilistic population projections to include probability distributions of the starting conditions of the projections.

In the field of probabilistic population projections essentially three different approaches have been evolving over the past years, which all have been inspired by the work of Nathan Keyfitz during the 1980s. A recent book entitled *Frontiers of Population Forecasting* (Lutz, Vaupel, and Ahlburg 1999b) provides a comprehensive review of these alternative approaches, which are also discussed in the recent NRC report on population projections (National Research Council 2000). The first one is based on the analysis of errors in past population projections and the assumption that future errors will be similar to past errors (Alho 1997; Keilman 1999; Lee 1999). The second approach is largely based on time series analysis and produces stochastic projections on the assumption of structural continuity and constant variability (Lee 1993; Lee and Tuljapurkar 1994). The third approach largely rests on argument-based expert opinion about the likely future range of uncertainty in fertility, mortality and migration (Lutz, Sanderson, and Scherbov 1997, 1999a). While the first two approaches usually distinguish between assumptions on the trend (which is mostly based on expert opinion) and the variance (which is derived from past errors or time series), under the third approach, trend and variance are assumed jointly by a group of informed experts evaluating alternative substantive arguments.

There is a considerable debate at the moment about which of the three approaches is the most appropriate one. This discussion, which seems to go into the direction of combining elements of the different approaches, is documented elsewhere (Lutz et al. 1999b) and cannot be summarized here. But it is important to note that the full range of options is only available for populations for which both a series of past projections and reliable empirical data for verification exist (for the first approach) and sufficiently long high-quality time series are available (for the second approach). These preconditions significantly limit the number of countries to which all three methods are applicable. As described in the introduction, South Africa does not belong to these countries. This means that we are essentially left with an expert-based approach. More theoretically it would also be interesting to consider the question of whether, even in the hypothetical case of available time series data, the HIV/AIDS pandemic represents the kind of structural discontinuity that would prohibit the meaningful application of the other two approaches.

For the objective of this study, namely an extension of probabilistic population projection methods to cover the uncertainty about starting conditions, the first two approaches are not feasible. The time series approach depends on reliable empirical data by its very nature and is meaningless without them. The approach of learning from past errors could theoretically be expanded to refer to errors about point estimates that have later been revised due to better empirical information becoming available. But this would need to be based on the assumption that certain bad estimates of the past that happen to be documented do have universal features or biases of a certain kind that can also be assumed for current population estimates. The problems around the 1996 census of South Africa, however, seem to be unique; it is difficult to think of any comparable and documented census undercount in South Africa under apartheid or in any other country that could readily give us an uncertainty distribution for the 1996 total population size. We are thus left with the third approach that is based on expert views and substantive arguments based on the best available evidence. In the following section we will try to summarize this evidence.

Demographic Trends and Assumptions in South Africa

Population Size and Structure

The population of South Africa is estimated to have grown from 4–5 million in 1900 to about 40 million in 1990 (Mostert et al. 1998). Estimates about the more recent conditions heavily depend on assumptions made about the spread of HIV/AIDS and the speed of fertility decline in South Africa.

As mentioned in the introduction, there are very significant differences between the estimates of different agencies and scientists concerning the population size of South Africa in the census year 1996 (see Table 1). Based on different interpretations of the coverage of the first post-apartheid census, published estimates of the total population range from 38.1 million (UN) to 44.0 million (DBSA). To make things worse, the age distributions associated with these differing estimates are even more deviant. For example, the size of the youngest female age group (0–4 years) is estimated at 2.51 million by the Bureau for Market Research (BMR 1999) and 3.32 million by the Development Bank of Southern Africa (see Table 3). The estimates of the youngest age group differ by 32%, while the total population estimates of these two agencies differ by less than 5%.

What should demographers do in the face of these hopelessly diverging estimates of the size and structure of the starting population? As discussed above, the usual procedure is to pick one estimate that is considered the best and simply forget about the others. In this case our clear favorite would be the BMR estimate because one of the authors of this paper has played a key role in its production and is, of course, convinced that it is the best estimate. But we decided to assign only a 50% probability to this one estimate, and distribute the other 50% to the remaining estimates. After extensive discussions and application of several criteria, the UN estimate was assigned a 10% probability, because it is clearly based on still uncorrected first census results, while the remaining two get 20% each.

Assigning such probabilities to discrete point estimates rather than to continuous ranges–as is done for fertility and mortality–was the only possibility because the age structure associated with the different estimates do not provide a meaningful continuum. In terms of output (results), however, a continuum is produced through the fact that in the process of 1000 independent cohort-component projection simulations, the discontinuous distribution of starting populations is soon smoothened by the application of randomly drawn vital rates. As the results will show, already after ten years this produces rather smooth uncertainty distributions, even for the age structure.

Table 1. Base populations (1996) in thousands used for the purposes of this study. Sources: Sadie (1993); Calitz (1996); Van Aardt, Van Tonder, and Sadie (1999).

	UN 1996		SADIE		BMR		DBSA (as adapted)	
	Females	Males	Females	Males	Females	Males	Females	Males
0 to 4	2,429	2,445	2,584	2,619	2,511	2,550	3,322	3,381
5 to 9	2,297	2,290	2,433	2,472	2,399	2,433	2,816	2,858
10 to 14	2,127	2,112	2,342	2,377	2,312	2,341	2,574	2,618
15 to 19	1,966	1,947	2,141	2,165	2,138	2,151	2,288	2,312
20 to 24	1,800	1,775	1,963	1,979	2,032	2,025	2,024	2,029
25 to 29	1,597	1,588	1,736	1,751	1,848	1,827	1,760	1,767
30 to 34	1,451	1,459	1,541	1,535	1,611	1,572	1,452	1,439
35 to 39	1,239	1,258	1,362	1,342	1,390	1,344	1,210	1,199
40 to 44	1,040	1,067	1,131	1,104	1,137	1,093	1,012	1,003
45 to 49	859	821	923	883	958	913	858	829
50 to 54	717	640	756	702	777	735	704	676
55 to 59	580	485	629	557	631	585	572	545
60 to 64	453	362	499	421	501	444	484	436
65 to 69	329	247	390	299	389	327	374	305
70 to 74	228	142	285	198	278	220	264	218
75 to 79	146	72	201	126	159	112	176	130
80+	115	43	217	108	169	92	204	108
TOTAL	19,373	18,753	21,142	20,647	21,249	20,771	22,097	21,861
TOTAL (F+M)	38,126		41,790		42,020		43,958	

HIV/AIDS and Life Expectancy

HIV/AIDS came to South Africa later than it came to countries further north on the continent. Dorrington (1999) estimates that in 1990 the average life expectancy at birth in South Africa was 63 years and less than 0.5% of the population was HIV positive. Only since 1995 is consistent empirical information available, based on the testing of blood samples of pregnant women at sentinel sites in all provinces of South Africa. These data for women aged 15–45 suffer from all kinds of biases that are extensively discussed in the AIDS literature and have impacts on estimates of total HIV prevalence (UN 2000). The main biases are due to the fact that the sample only includes sexually-active women who for this reason also have a higher probability to be infected and, on the other hand, due to the fecundability reducing effect of HIV (fewer HIV infected women may become pregnant). Although these two biases may partly offset each other, there are many more possible confounding factors relating to heterogeneity with respect to sexual networking, migration, etc., that cast doubts on the representativeness of the data. But since these sentinel site data are the best empirical information available, they tend to be taken as the basis of most estimates of HIV prevalence in developing countries.

Table 2 gives the HIV prevalence rates since 1995 for the nine provinces of South Africa and for the national aggregate. They show very strong increases in most regions with the highest prevalence in KwaZulu-Natal with well above 30%. The 1999 ante-natal survey results have only recently been published and there are some doubts, especially about the validity of the national figure that would indicate a stabilization of infection rates. If the national average is not simply derived by pooling the data, but instead weighted appropriately by age and size of province, the data still imply a further increase.

Table 2. HIV prevalence rates for South Africa and its nine provinces as found at sentinel sites. Source: Marais (2000).

	1995 %	1996 %	1997 %	1998 %
South Africa	10.4	14.1	16.0	22.8
Eastern Cape	6.0	8.1	12.6	9.9
Free State	11.0	17.5	19.6	22.8
Gauteng	12.0	15.5	17.1	22.5
KwaZulu-Natal	18.2	19.9	26.9	32.5
Mpumalanga	16.2	15.8	22.6	30.0
Northern Cape	5.3	6.5	8.6	9.9
Northern Province	4.9	8.0	8.2	11.5
North West	8.3	25.1	18.1	21.3
Western Cape	1.7	3.1	6.3	5.2

The age profile of HIV infection shows a peak for women in the age groups 20–24 and 25–29 where infection rates are above 26% on the national average. Since these are cross-sectional data and for cohorts, infection rates are cumulative (unless there is a major behavioral change instantly), and the total risk for young female cohorts can be assumed to be around 50% (UNAIDS 1998).

These exceedingly high infection rates of young women, however, cannot be directly translated into infection rates of the total population including elderly people. Also, very little is known about the infection rates of men, which are assumed to be lower than those for women. The estimates given in Table 3 are adjustments of the data shown in Table 2 as adapted to pertain to the whole population of each province. Such adaptation of the sentinel site data was conducted by making use of HIV-prevalence modeling results published by Dorrington (1999) and Kipps and Gouws (1998). The HIV sero-prevalence rates shown in Table 3 were used in this study to derive both estimates for current levels of life expectancy and possible future HIV prevalence rates required to derive future life expectancy assumptions for the population projection conducted in this study, as will be discussed below.

Table 3. HIV prevalence rates in the total population for South Africa and its nine provinces. Sources: Based on Marais (2000); Kipps and Gouws (1998); Dorrington (1999).

	1995 %	1996 %	1997 %	1998 %	1999 %
South Africa	4.5	5.8	7.6	9.9	12.9
Eastern Cape	2.4	3.3	4.5	6.2	8.6
Free State	4.4	5.8	7.6	10.0	13.3
Gauteng	4.8	6.1	7.7	9.5	11.7
KwaZulu-Natal	7.3	9.2	11.6	14.5	17.8
Mpumalanga	6.5	8.2	10.4	13.1	15.8
Northern Cape	2.1	2.7	3.5	4.6	6.0
Northern Province	1.9	2.7	3.7	5.1	7.1
North West	3.3	4.5	6.2	8.6	12.0
Western Cape	0.7	1.2	1.9	3.1	4.3

Figure 1 graphically depicts our assumptions with respect to the trend and uncertainty of future life expectancy for both sexes combined. This assumed pattern is unusual in three different ways:

1) It includes a strong discontinuity with a downward trend in the median until 2015, followed by a recovery. This assumption is based on the expectation that the rates of new HIV infection (incidence) will start to level off or decline over the coming decade, with AIDS mortality reaching a peak around 2015. Such a saturation process is also assumed by the UN (2000) and the recent state of the art summary by the National Research Council (2000). It cannot be discussed here in any detail, but it is based on a combination of assumed behavioral change, medical intervention and the natural saturation dynamics of any epidemic.

2) Since the level at which such saturation will occur is still highly uncertain, the mortality assumptions up to 2030 cover an extraordinarily wide range of possible levels. Life expectancy at birth in 2015 is assumed to lie (with a 95% probability) within a range of almost 30 years to around 65 years. This is by far the widest range of mortality uncertainty that the authors ever assumed in probabilistic projections or alternative mortality scenarios (see Lutz, Sanderson, and Scherbov 1996). Since other agencies like the UN or the US Census Bureau only define one mortality path and leave aside the issue of uncertainty, this assumption cannot be compared to other population projections.

3) The third unusual feature is the fact that the range of uncertainty is assumed to narrow somewhat after 2015, which is in contrast to the usually assumed broadening of uncertainty over time. Here it is simply a consequence of the extreme uncertainty around the year when AIDS mortality is assumed to peak,

with a slow move towards more regular conditions–including the assumption of a catching up process–thereafter. Still the range of 41 to 67 years in 2030 is extremely broad by any standard.

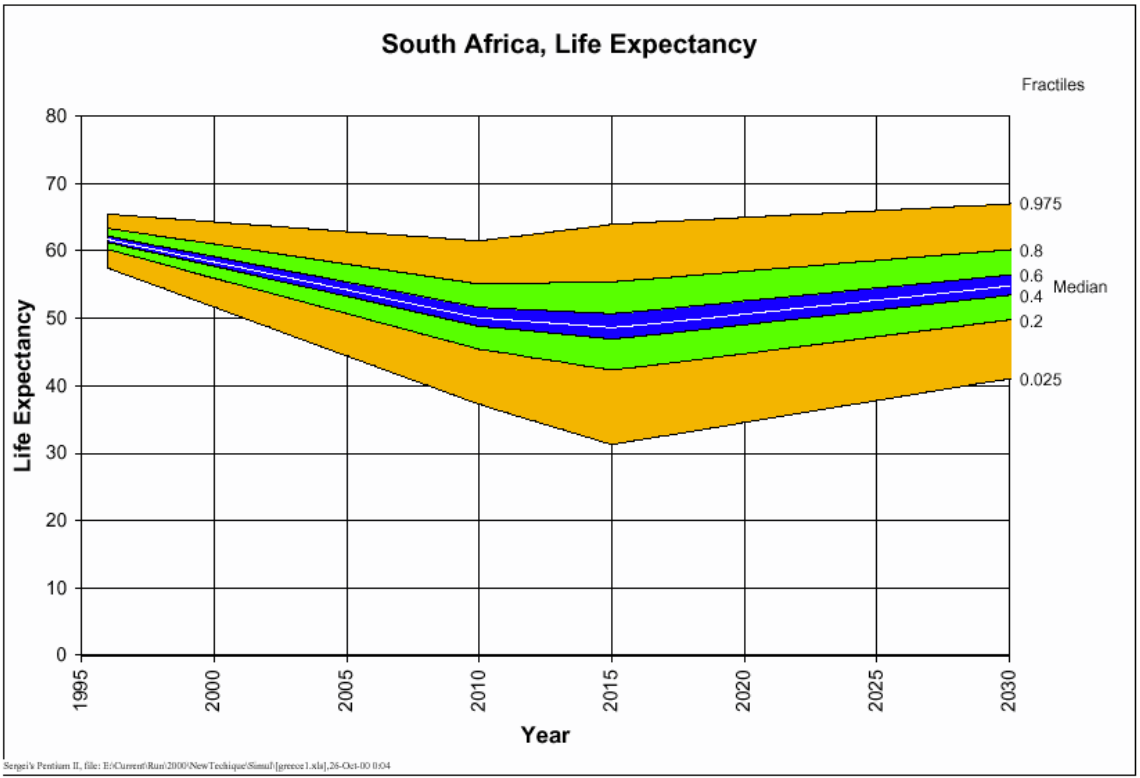

Figure 1. Life expectancy, both sexes.

Fertility

It appears from previous South African censuses, vital registration systems and sample surveys, that the fertility rates of all population groups have been declining dramatically from the 1930s onwards, but not all at the same pace. (It should, however, be noted that the reliability of such data is questionable, and here especially with respect to the Black population). The total fertility rate (TFR) of the White population decreased from about 4.5 in 1910 to about 3.4 in 1950, to about 1.8 in 1990. The TFR of the Black population remained stable at about 6.6 during the period 1930 to 1960, whereafter there was a steep decline in fertility rates to about 4.7 in 1990. The TFR dynamics of the Asian and Colored populations were very similar over the period 1930 to 1990, in the sense that both were between 6 and 7 in 1930, followed by a steep decline to be between 2 and 3 by 1990.

The downward trend in the TFR of the South African population as a whole during the past few decades is evident from the fertility estimates of both Sadie (1998) and Udjo (1998). According to Sadie's estimates, the TFR in South Africa dropped from 5.73 in 1970 to 3.49 in 1995, while Udjo's estimates suggest that the TFR dropped from 4.9 in 1970 to 3.2 in 1995. Irrespective of whether Sadie or Udjo is closer to the mark, they both indicate strong downward trends in South African fertility rates.

As to the specific fertility assumptions of this study, for the starting year of the projections it was assumed that the real fertility rate of 1996 is normally distributed around 3.2 with 90 percent of the possible levels lying between 2.4. and 4.0. The tails of the normal distribution also provide for the unlikely cases that fertility in 1996 actually falls outside this range.

As to the future trend in fertility, the median is assumed to decline from 3.2 in 1996 to 3.0 in 2001 and then linearly to 2.0 in 2025. The range of uncertainty assumed around this trend is again very significant because it is not clear how fertility will respond to HIV/AIDS. There are many indications that it may accelerate the fertility decline, but it could also evoke more traditional responses of higher fertility after a mortality crisis. In terms of TFR the assumed 90% interval covers a range of 1.6 children around the median, i.e., moving from a range of 2.4–4.0 in 1996 to 1.2–2.8 in 2025.

Figure 2 shows the implications of these fertility assumptions for the total number of births, which is also influenced by the population age structure. Therefore, it shows a slight increase over the first years. After 2005 the median of the uncertainty distribution shows a slow decline, which is a combined effect of a declining TFR and an age structure decimated by AIDS mortality. Unlike for the TFR where the range of uncertainty is assumed to be constant in absolute terms, here the range of uncertainty increases over time due to the increasing age structural uncertainty.

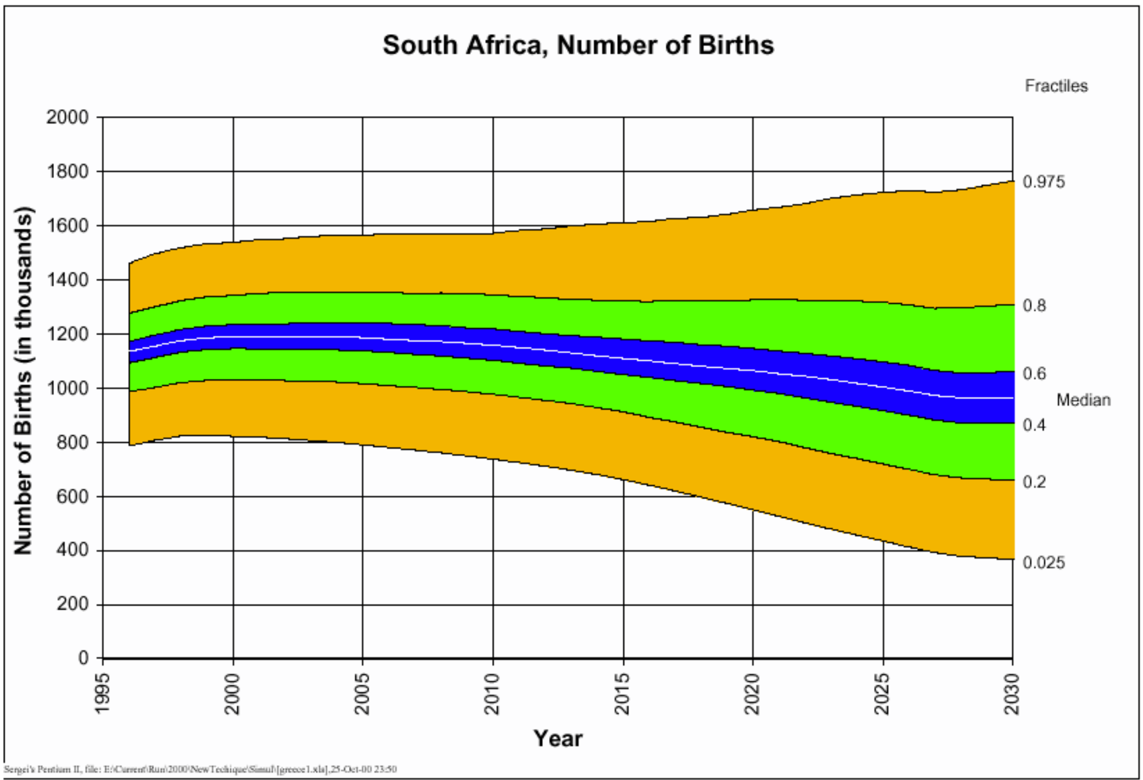

Figure 2. Number of births.

International Migration

It appears from data supplied by Statistics South Africa (StatsSA 1999) that net international migration gains and losses were minimal during the 1990s. The current international migration statistics imply that there is a very small net loss of whites and a net gain of blacks, although such gains and losses are not of a significant magnitude in their impact on population outcomes compared to the impact of fertility and mortality on the population dynamics of South Africa. Significant international migration gains and losses are also not foreseen during the immediate future. For this reason no strong future migration impacts (i.e. average net migration of zero) were catered for in the population projections discussed in this paper.

Results

Figure 3 shows the resulting uncertainty distribution for total population size over time. It shows that unlike projections for neighboring Botswana (Sanderson 2000), the population of South Africa is unlikely to actually enter a decline due to AIDS. The median of the distribution still shows a rather steep increase to around 52 million by 2015, followed by a slower increase and eventually leveling off. Despite AIDS, this early increase is due to the still very young age distribution and an assumed TFR with a mean above 3.0.

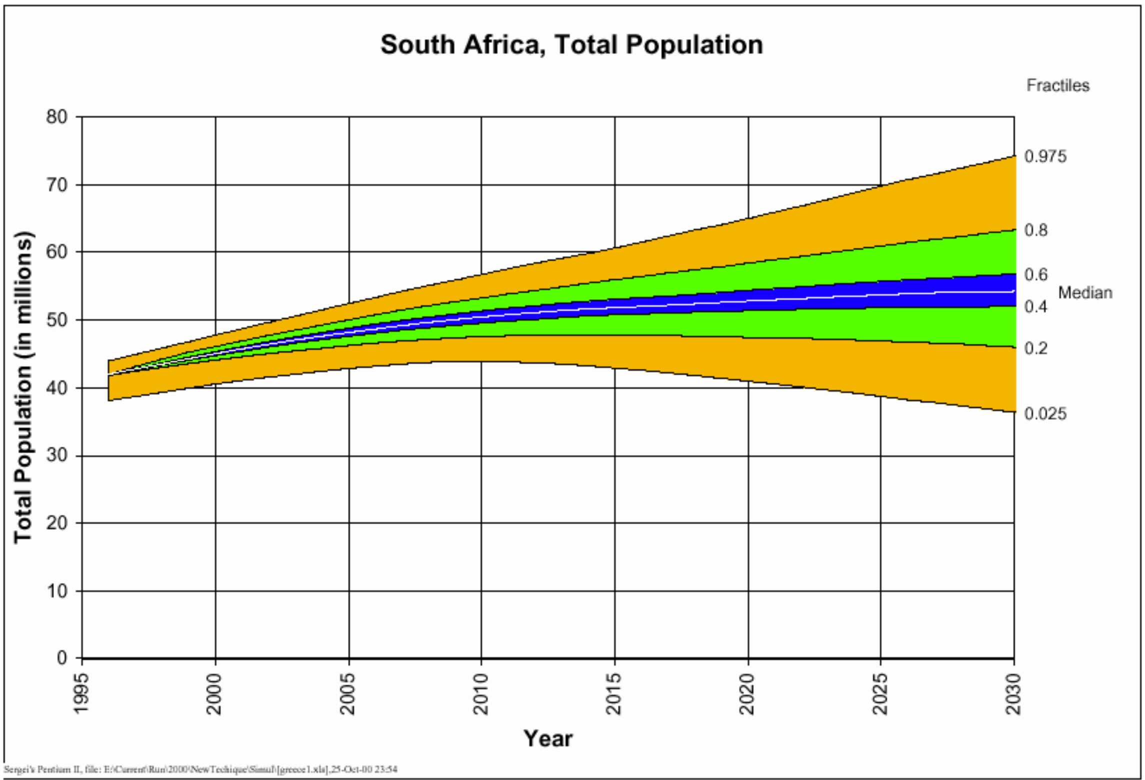

Figure 3. Total population.

Due to the alternative estimates of the starting conditions there is already a sizeable uncertainty in 1996, with a highly non-symmetric distribution as a consequence of the much lower UN estimate. The distribution becomes roughly symmetric only after 2015 due to assumed symmetry in vital rates uncertainty.

Uncertainty in total population size strongly increases over time. By 2015 our simulation results show a probability of 60% that the South African population will be between 47 and 56 million, and a probability of 95% that it will lie between 41 and 61 million (see Table 4). By 2030 these ranges increase to 44 to 64 million (60%) and 34 to 76 million (95%).

Table 4. Summary of results. Median and uncertainty ranges for selected output variables.

		Median	60%	95%
Total Population	2000	45.0	44.1-46.1	40.4-47.7
	2015	51.8	48.0-55.8	42.7-60.8
	2030	54.2	46.5-63.0	36.3-73.8
Proportion below age 20	2000	.449	.439-.473	.428-.496
	2015	.414	.380-.445	.326-.480
	2030	.354	.314-.391	.246-.431
Proportion above age 60	2000	.066	.062-.067	.060-.069
	2015	.082	.075-.087	.067-.096
	2030	.105	.092-.119	.079-.142
Old-Age Dependency Ratio	2000	.137	.136-.139	.124-.140
(60+ / 20-60)	2015	.165	.149-.168	.139-.175
	2030	.194	.176-.213	.155-.237
Dependency Ratio	2000	1.059	1.025-1.156	.984-1.261
(60+ plus 0-20) / (20-60)	2015	.984	.873-1.091	.722-1.221
	2030	.851	.758-.940	.634-1.053

Different age-structural indicators show different degrees of uncertainty. This differential degree of uncertainty by age is most clearly visible from the probabilistic age pyramid as depicted for 2030 in Figure 4. This figure gives the same fractiles as indicated in Figure 3 (median, inner 20%, 60%, and 95%) but for single years of age. Generally, the picture shows that the younger the age group, the higher the uncertainty. For cohorts born before 1965–70 the uncertainty is relatively small, since they are already beyond the main years of AIDS mortality, and there is no great difference in terms of alternative starting conditions for these age groups. For the cohorts born 1990–1996 the 95% uncertainty interval is clearly asymmetric, due to the much higher size of the youngest age groups in the DBSA estimate. This results in a visible discontinuity to the cohorts born after 1996, which are derived from the probabilistic fertility rates applied to more symmetrically distributed cohorts of mothers. For the youngest age groups in 2030, the uncertainty is extraordinarily large due to the combination of fertility uncertainty, uncertainty about the sizes of the parent's cohorts and mortality uncertainty.

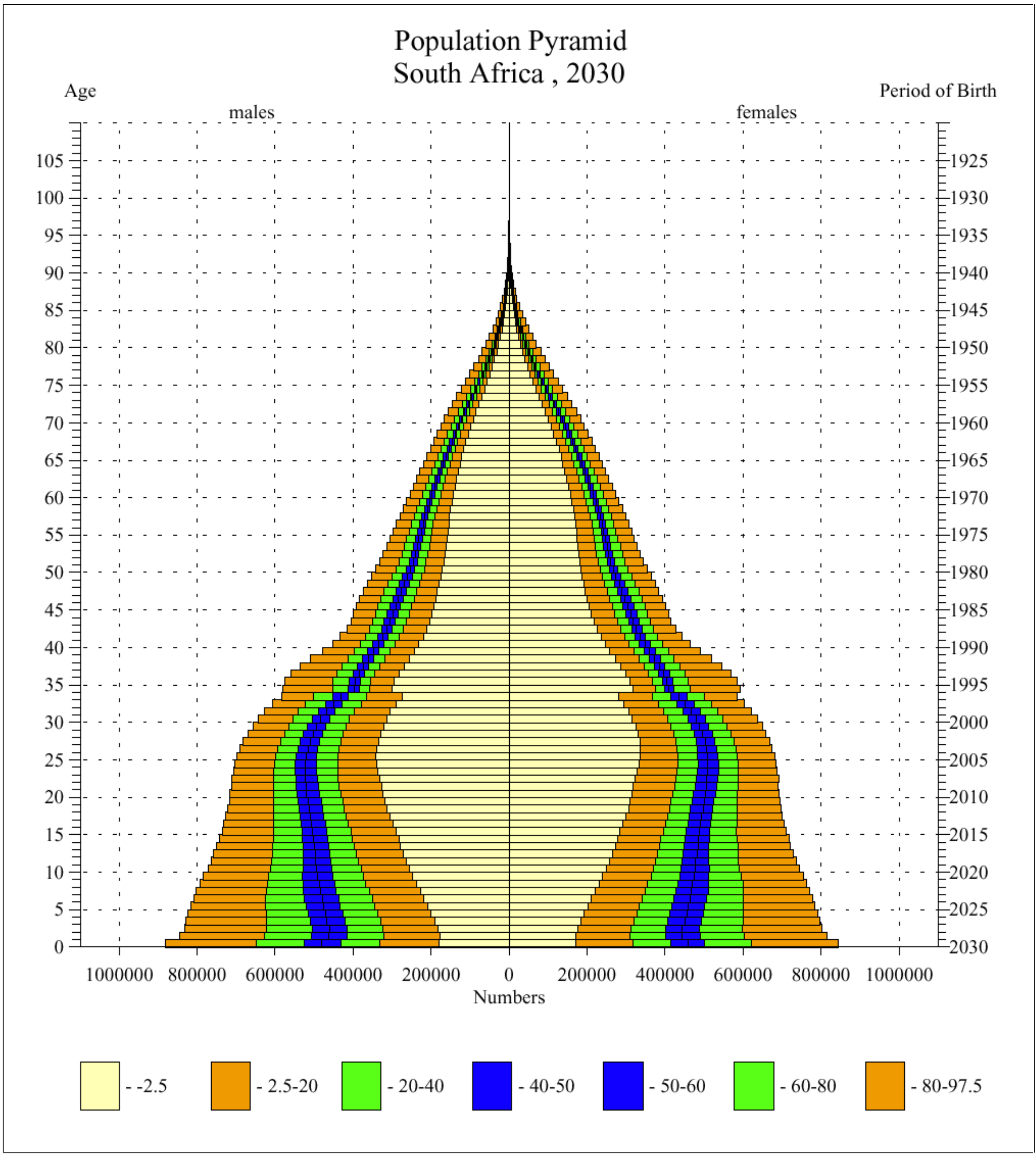

Figure 4. Population pyramid.

Superimposed on this pattern of increasing uncertainty for younger cohorts are two additional features: the aging shape as implied by declining fertility, and a reduction at the center due to high AIDS mortality for young adults. While the first is clearly visible from the narrowing bottom of the age pyramid (at least for 80% of the simulations) the latter is less obvious. But if one looks at the dark area, i.e., the inner

20% of the distribution, then a discontinuity starting with the cohorts born 1970–75 is visible in the sense that these age groups are significantly smaller than would have been the case under given fertility rates and no HIV/AIDS, in which case the lines would have been pulled more to the outside, making a “fatter” pyramid for the cohorts born 1970 to 2000.

Table 4 also summarizes the results in terms of the proportions below age 20, above age 60, and demographic dependency ratios. As a consequence of declining fertility and vertical HIV transmission the proportion of the young population is likely to decrease but the old age dependency ratio is likely to increase. But there is great uncertainty associated with both trends. Since AIDS mortality will mostly hit the younger adults, the AIDS impact on the old age dependency ratio is rather neutral with the AIDS uncertainty being entered through the uncertainty in total population size. Since the expected proportional decrease in the young population is likely to be stronger than the increase in the elderly population, the total dependency ratio has a tendency to decline over time, even though AIDS kills people in their main working ages.

Conclusions

This paper made a very ambitious effort to summarize the best that we know about the future of the South African population. It is ambitious because there is not only high uncertainty about the future trends in vital rates, but also great uncertainty about the current population size, age structure and fertility and mortality levels. Trying to capture the possible dynamics of the HIV/AIDS pandemic in South Africa poses an additional major challenge.

Faced with all these uncertainties and problems, conventional approaches to population forecasting would have either done a fairly unrealistic job by simply ignoring much of the uncertainty, or on the other extreme, demographers might refuse to make any forecasts because the uncertainties are considered too significant. Here we try to develop a compromise between the two extremes by expanding the approach of expert- and argument-based probabilistic population forecasting to include uncertainties about starting conditions. No other probabilistic approach could have dealt with this task because neither time series analysis nor ex post error analysis are applicable for this situation. This paper indeed demonstrates that there are better ways of dealing with present and future uncertainties than those of conventional population projection approaches. By trying to quantify the uncertainties, such probabilistic projections can at least give some meaningful advice on possible future trends in South Africa to national and international planners. In face of the overwhelming humanitarian, social and economic challenges facing South Africa, such projections are more urgently needed for planning than in many other countries having more accurate data and less discontinuous trends. Demographers should not shy away from creatively attacking such challenges and be ready to revise the projections as soon as more and better information becomes available.

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