As the ASSA2000 Urban-Rural model still needs some fine-tuning and the calibration of the model to the individual countries is at best rudimentary at this stage the figures are for illustration purposes and not to be quoted without first speaking with the author.

"FITTING THE ASSA2000 URBAN-RURAL AIDS AND DEMOGRAPHIC MODEL TO 10 SUB-SAHARAN COUNTRIES"

BY ROB DORRINGTON AND DAVID SCHNEIDER

ABSTRACT

This paper describes the fit and the results of that fit of the ASSA2000 urban rural model to the following sub-Saharan countries: Botswana, DR Congo, Kenya, Malawi, Mozambique, Namibia, Tanzania, Uganda, Zimbabwe and Zambia. In order to fit the models national prevalence estimates first had to be extrapolated as a weighted average from the sentinel site data on the basis of a distribution of the population over time. In addition to this the models require, inter alia, estimates of a base population, non-HIV fertility and mortality rates, and migration. These data were scanty in many of the countries but in most cases the authors made use of estimates of either the UN or the US Census Bureau, and where available a recent DHS. Other parameters were set in order to best reproduce the pattern of prevalence in the past taking into account any known changes in behaviour. The paper presents various summary statistics for each of the countries, including 4q1, 45q15, e0, and numbers of infected people, and numbers of AIDS deaths. The models can be downloaded for use by researchers.

KEYWORDS

HIV, AIDS, model, population projection, prevalence, mortality, sub-Saharan

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1. INTRODUCTION

The ASSA model has its origins in the Doyle-Metropolitan model originally proposed by Doyle and Millar (1990). As this model was proprietary to Metropolitan Life the AIDS Committee of the Actuarial Society of South Africa (ASSA) decided to develop a spreadsheet model which could be used by insurers, researchers and policymakers to assess the impact of HIV on mortality rates. This model (ASSA500) was a model of a hypothetical (African) population.

In 1998 the Committee constructed the ASSA600 version. It was described at the time as an AIDS model of the third kind (Dorrington, 1998) for two reasons, first to distinguish it from 'macro' and 'micro' AIDS models, but more importantly to distinguish it from the traditions of AIDS models which ignore demographic imperatives (or at most afford them second class status) and demographic models which at that stage, at least in South Africa, were ignoring the impact of HIV/AIDS (and even today still afford it second class status). The big advantage of modelling both together is that not only does the model produce better demographic projections but also it gives more to check the model against in the sense that it produces realistic and measurable demographic outputs. In particular, in the case of the ASSA2000 model, the model has been calibrated against the deaths (recorded by the South African Department of Home Affairs and corrected for under-reporting (Dorrington *et al*, 2001 and Timaeus *et al*, 2001).

Most populations are demographically and epidemiologically heterogeneous and few more so than South Africa with its apartheid past. For this reason, amongst others, it was considered necessary to model the impact of the epidemic using four distinct sub-populations (based on self-classification into four race groups, Asian, black African, coloured (predominantly the descendants of the Koisan and parents of different races) and white (predominantly the descendants of European immigrants).

Having developed such a model, and given the relatively successful tracking of the epidemic as measured by the antenatal clinic prevalences shown by the ASSA600 model, we decided to adapt this model to model the epidemic in populations where there are significant differences between urban and rural epidemics, not to say demography, which is the case in sub-Saharan countries (with the exception, possibly, of South Africa). This paper reports on our initial efforts to construct and fit such a model to 10 sub-Saharan countries.

Further work is needed, preferably with collaborators living and working in each of these countries who will better understand the dynamics of the population in their specific countries, to improve the parametisation and calibration of the models before the output could be regarded as reliable. In order to encourage such collaboration and investigation and use of the models we will be placing 'alpha versions' of the models on the ASSA website (www.assa.org.za) to be freely downloaded.

The paper begins with a brief overview of the ASSA2000 model. This is followed by a description of the adaptations made to this model in order to create the urban-rural version and the data requirements to fit the model, a section outlining the major sources of data and a presentation of the major results. More detailed results are presented in the appendices. Appendix A illustrates some of output from the model by giving greater detail on one country, Namibia and Appendix B gives a summary output for the eight other countries. The paper concludes with an illustrative attempt to incorporate behavioural change into the model in the case of Uganda, and a discussion of the results.

2. BRIEF DESCRIPTION OF THE ASSA2000 MODEL

A detailed description of the ASSA600 model appears in Dorrington (1998) and an update in Dorrington (1999a).

The ASSA2000 suite of models was developed in 2000[i]. The following are the major improvements on the ASSA600 model:

- adjustments to incorporate updated empirical data and understanding of the epidemic
- improvements to the model to
    - improve the fit to ANC survey data
    - allow for the possibility of making separate male and female assumptions
    - model the population groups separately
    - limit the trend in mortality and fertility rates over time
    - limit future in-migration
    - change HIV survival curve to be a function of a Weibull distribution
    - allow for bimodal distribution of paediatric HIV survival
    - disaggregate the 'contagion matrix' into more measurable and controllable sexual behaviour parameters.
    - calibrate the model to the most recent estimates of mortality.

These changes are documented in more detail in Dorrington (2001).

The ASSA model is a component population projection model which models the demographic impact of the heterosexual epidemic only. The ASSA2000 version of the model is a significant advance on the earlier versions in that it attempts to model sex activity as part of this process. This enhances the usefulness of the model as a tool to assess the impact of various behavioural changes and intervention strategies. A brief description of the model appears in Appendix C.

As illustrated by the figure in Appendix C the model splits the population into sub-groups depending on various risk factors associated with the mechanism of transmission and chance of becoming infected, namely:

- Age (0-13, 14-59, and 60+)
- Behaviour (about 1% of the population in the high-risk (PRO) group (e.g. commercial sex workers and their clients), about 20% are those who regularly suffer sexually transmitted diseases (STDs) which significantly increase the probability of transmission, about 30% simply behave in a risky way (RSK), and the remainder of the population is assumed not to be significantly exposed (NOT))
- Race (which may be a proxy for various socio-economic factors, and in particular a measure of previous, and continuing, social disadvantage)

At present the model does not take into account sex between people from different population groups (races)[ii].

3. ADAPTATIONS TO PRODUCE THE ASSA2000 URBAN-RURAL MODEL

3.1 *Overview*

In order to model the spread of the Pattern II (heterosexual) HIV/AIDS epidemic within a sub-Saharan African country we had to model separately the urban and rural populations (since these population groups have markedly different demographic profiles and sero-prevalence levels). In addition the model had to allow for the spread of the epidemic in these two population groups, as well as migration between rural and urban areas.

The ASSA2000 Urban-Rural model is based on the ASSA2000 model. In essence the ASSA2000 model was stripped to two population groups and the migration structure enhanced to allow for net urbanization (in addition to the net international migration already incorporated into the model).

Currently the model we have derived does not automatically allow for a change in sexual behaviour (experienced in countries such as Uganda, where antenatal sero-prevalence levels have been falling sharply since the early 1990s). In order to allow for changes in behaviour the user has to decide on the pattern of change likely to be experienced over time and alter the assumptions for those years directly.

We are investigating the possibility of developing some sort of “trigger” which would signal the start of a change in the number of partners, usage of condoms, and number of contacts per partner, based on a key statistic (e.g. proportion of individuals who “know” [yet to be defined] someone who has died of AIDS).

In section 6, by way of example, we show the impact of a somewhat arbitrary change in the number of new partners per annum and the proportion of the urban population engaging in risky sexual behaviour on the prevalence levels in Uganda.

3.2 *Additional data required to run the ASSA Urban-Rural model*

In addition to the standard assumptions (relating to transmission probabilities, survival time to death from sero-conversion, number of partners per risk group, etc) the user needs the following additional input:

(a) *Antenatal prevalence*: antenatal sentinel data by site and split by urban and rural testing centres. A weighting can be associated with each site. The user can also decide whether to use a median, crude average or weighted average of the various sites to derive the estimate antenatal sero-prevalence for each of the urban and rural population. The national prevalence is based on a weighted average (by number of pregnant women in the population) of the urban and rural total results;

(b) *Non-AIDS mortality*: the user needs to input male and female non-AIDS mortality rates by (individual) age for both the urban and rural regions, as well as a non-AIDS mortality improvement index;

(c) *Fertility*: the user needs to input the total and (individual) age specific fertility rates for both the total and the urban populations for each calendar year between 1980 and 2000. These are non-HIV fertility rates as the model explicitly allows for the effect of HIV infection on fertility by age and duration since sero-conversion;

(d) *Migration*: the user is required to input the number of migrants by (individual) age and sex from the rural regions into urban centres as well as the total net immigration per annum to be assumed for each year;

(e) *Starting population*: The user needs to input starting population profiles by (individual) age and sex of both the total and the urban populations;

(f) *Other data*: before calibrating the model the following data is also required:

- The proportion of adults with an sexually transmitted diseases within each country (split by sex, and urban and rural region);
- The age profile of the sexual partners of women at each age;
- The proportion of adults engaged in commercial sex work (split by sex, and urban and rural region);
- The proportion of the population who use condoms by age in each of the risk groups;
- The proportion of urban and rural women who make use of public health clinics.

Ideally this data should come from national demographic and health surveys but if suitable estimates are not available (as is the case in many sub-Saharan countries) the model uses a set of default assumptions based on the population in the KwaZulu-Natal province of South Africa.

3.3 *Overcoming the shortage of data*

Clearly most of these data are difficult to obtain, and in order to assist the user we have created a template for the model, which allows one to generate the required input where only a limited amount of data is available. This is not the ideal but it allows one to make use of as much country-specific information (as opposed to being forced to use generic assumptions) as one can.

3.3.1 *Non-AIDS mortality*

For the non-AIDS mortality the user can input data in the following summary form, and the model derives mortality rates $\{q_x\}$ at individual ages, assuming Beers six-term formula to interpolate values between quinquennial age bands from age five and up. l_2, l_3 and l_4 are derived from l_1 and l_5 using a fixed set of factors derived examining the proportion the deaths from age x to age five were of the deaths from age one to age five in the Coale and Demeny (1996) model life tables. l_5 was derived using ${}_4m_1$ and an assumption of deaths over the interval that was consistent with these factors.

Age Range	$1000q_x$-over range		$1000m_x$-over range	
	Males	Females	Males	Females
0- 1	81.69	72.17		
1- 5			17.69	14.00
5-10			5.96	3.57
10-15			2.41	1.45
15-20			4.12	2.51
20-25			5.66	3.47
25-30			5.93	3.67
30-35			6.29	3.94
35-40			7.46	4.58
40-45			8.69	5.58
45-50			11.22	7.33
50-55			15.31	10.23
55-60			21.24	14.60
60-65			32.03	22.87
65-70			47.34	35.58
70-75			74.84	60.12
75-80			117.19	101.85
80+			234.99	227.49

The default non-AIDS mortality improvement factor is set to one (i.e. no improvement). The user can adjust this factor to allow for future improvement.

3.3.2 *Fertility Rates*

Fertility rates are generated for individual years and ages using the following input:

(a) An estimate of the non-HIV TFR over several calendar years (for the urban population and the total population), and

(b) ASFRs in five-year age groups for two separate years between 1980 and 2000.

Using this input a macro fits a relational Gompertz curve and uses the trend in the TFRs to generate two matrices of ASFRs at individual ages and for individual years, one each for the urban and rural populations. An example of the data required is shown in Appendix A (A1.1.3) for Namibia.

3.3.3 *Migration*

To derive a net number of rural residents who migrate to urban centres the user need only input the proportion of the population who live in urban centres at two points in time. The proportions at other points in time are derived from a logarithmic curve fitted to these two proportions. In all countries except Botswana the age distribution of these migrants was assumed to be the same as that found to be appropriate in an exercise reconciling the 1970 and 1996 South African census population estimates (Dorrington, 1999b). This distribution is shown in the figure below.

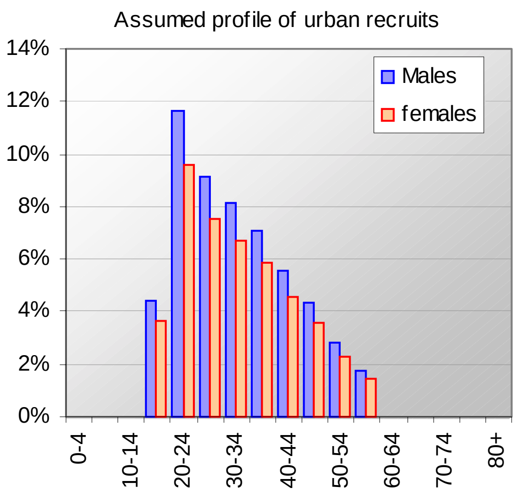

Figure 1: The assumed profile of net urban recruits

In the case of Botswana this distribution produced unreasonable results and the distribution was deduced from a reconciliation of the projected populations with the numbers in the urban areas by age recorded in the most recent census.

3.3.4 *Other assumptions*

As these data were difficult to find and the little that was available appeared to be unreliable we decided for this exercise to use the default assumptions which are based mainly on data from the KwaZulu-Natal province of South Africa.

Some of the default assumptions are:

- proportion of population with a STD: 25%, urban and 15%, rural;
- proportion of population engaged in commercial sex work: 1.2%
- proportion of women who attend Ante-Natal Clinics: 95%, rural and 90%, urban (assumed to higher than in KwaZulu-Natal)
- Ratio of TFR for Urban centres to total population: 75%
- Number of new partners per year and number of contacts per partner for each risk group, the age distribution and the risk group of partners and condom usage were all set the same as for KwaZulu-Natal and are shown in Appendix D.

3.4 *Calibration*

Given these assumptions the model was calibrated to reproduce as closely as possible the observed urban, rural and overall antenatal prevalences by altering the proportions in the RSK and STD risk groups.

4. DATA USED AND ASSUMPTIONS MADE

4.1 *Base populations*

Base population was estimated using the U.S. Census Bureau’s International Data Base (US Census Bureau, 2000) estimates of the total population and the age distribution taken from UN population estimates (UN, 1999). This was done so that we could make use of the US Census Bureau’s estimates of the urban population, if no other estimates were available.

The numbers at individual ages were interpolated using Beers six-term formula from the numbers in quinqunnial age groups.

4.2 *Non-AIDS mortality*

Generally estimates of mortality rates were determined from the survival rates implied by the UN (1999) projections. Where country-specific estimates could be found (e.g. Zimbabwe) these were used instead. In the case of Tanzania the estimate had to be based on the 1974 table in the US Census Bureau International Database (2000) as the UN appear not to have published population projections for Tanzania.

Due to a lack of data we have not specified differing mortality rates for urban and rural districts (even though one might reasonably assume that urban mortality has a higher accident ‘hump’ and rural mortality may possibly have a higher natural death rate). Furthermore we have not allowed for any improvement in non-AIDS mortality from the start of the epidemic until 1999, which is probably not unreasonable over recent years in the case of adults but probably not reasonable for children under five. Beyond this the mortality rates are assumed to tend towards a set of ultimate rates at a rate depending on the ‘improvement’ factor chosen.

4.3 *HIV/AIDS survival*

The same survival distributions were used as in the ASSA2000 model except the median term to death was assumed to be 10 years, for ages up to 34 and 9 years for alder ages.

4.4 *Non-HIV fertility*

The model requires age-specific fertility rates between 1980 and 2000. Historic TFR as well as the two ASFR schedules were taken from US Census Bureau’s IDB database (US Census Bureau, 2001).

We have assumed (arbitrarily) that urban fertility is 75% of total population fertility.

4.5 *Sentinel site antenatal data*

In the absence of population data split geographically in sufficient detail to allow for weighted averages to be calculated we have used a crude average of all the sentinel data points in order to derive the overall urban and rural ANC prevalence rates. National prevalences were derived as weighted averages of the urban and rural ANC overall results, with the weightings based on the total number of HIV+ pregnant women in urban and rural centres of each country.

4.6 *Migration*

The model allows for both net migration into urban areas as well as into the country as a whole.

Data on migration are difficult to find or derive. For the purpose of this paper we have assumed that there is no net international migration. Urbanization is modelled as described above. A detailed example is given in the case of Namibia, in Appendix A.

4.7 *Other assumptions*

In the absence of any convincingly reliable data default assumptions outlined above were used for the following:

- The proportion of births that take place in private facilities.
- The proportion of the population with sexually transmitted diseases (STD).
- The proportion of the population who are commercial sex workers or regular clients of commercial sex workers (PRO)
- Age of partner
- Level of condom usage.

5. RESULTS

Details of the fit to each country, the impact on total population size, then numbers of infected people in the population, number AIDS sick and the cumulative number of AIDS deaths for each country are given in the appendices. Below compare the antenatal prevalence levels, 4q1 and e0.

5.1 *Antenatal prevalence levels*

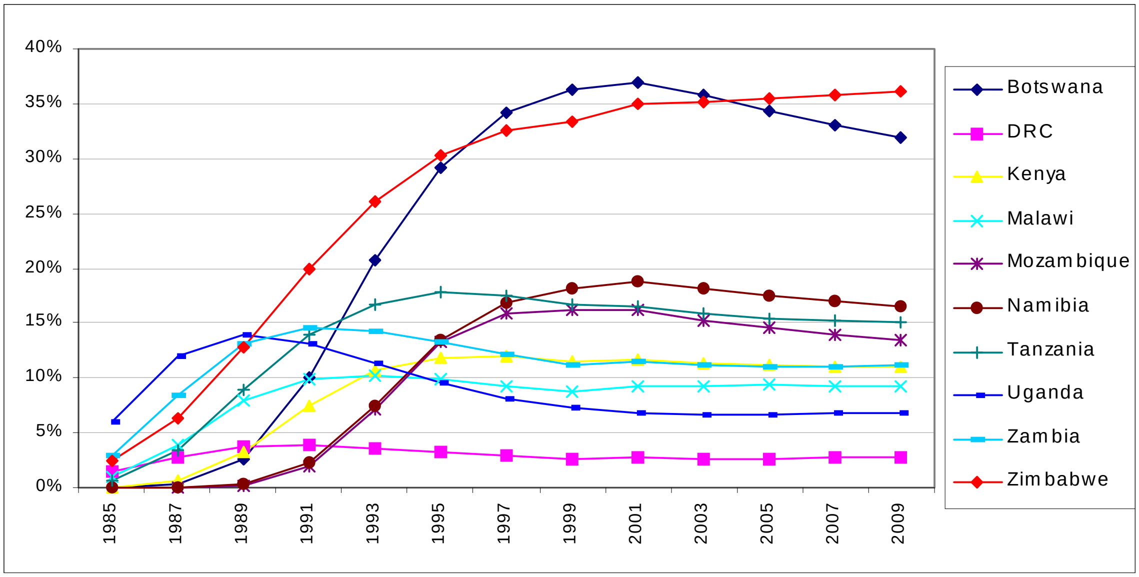

Figure 2: Country-specific estimates of antenatal prevalence

5.2 *Childhood mortality* ($_4q_1$)

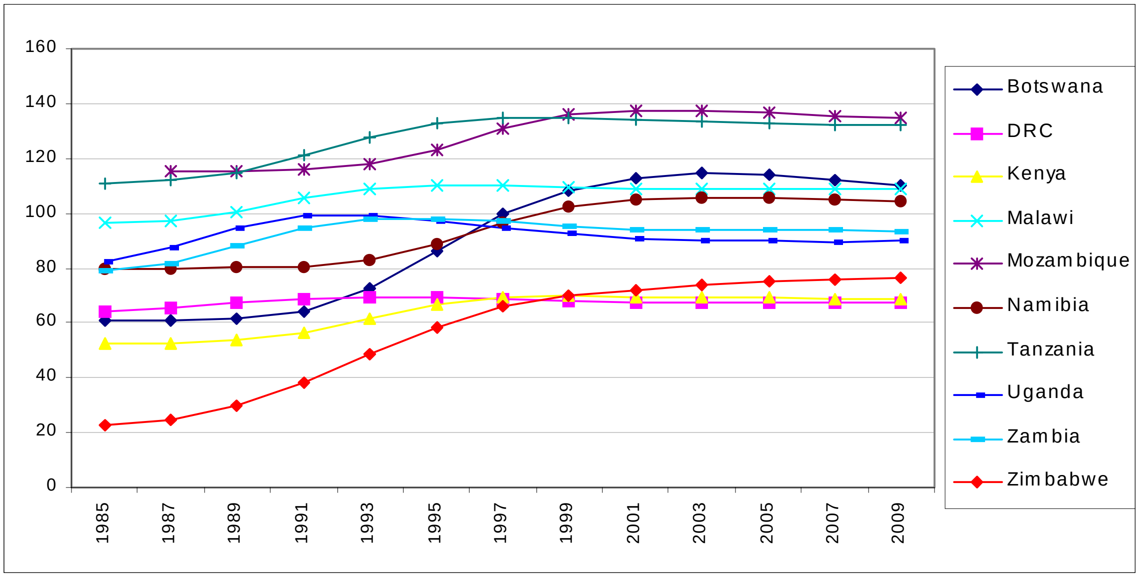

Figure 3: Country-specific childhood mortality ($1000\,_4q_1$)

5.3 *Adult mortality* ($_{45}q_{15}$)

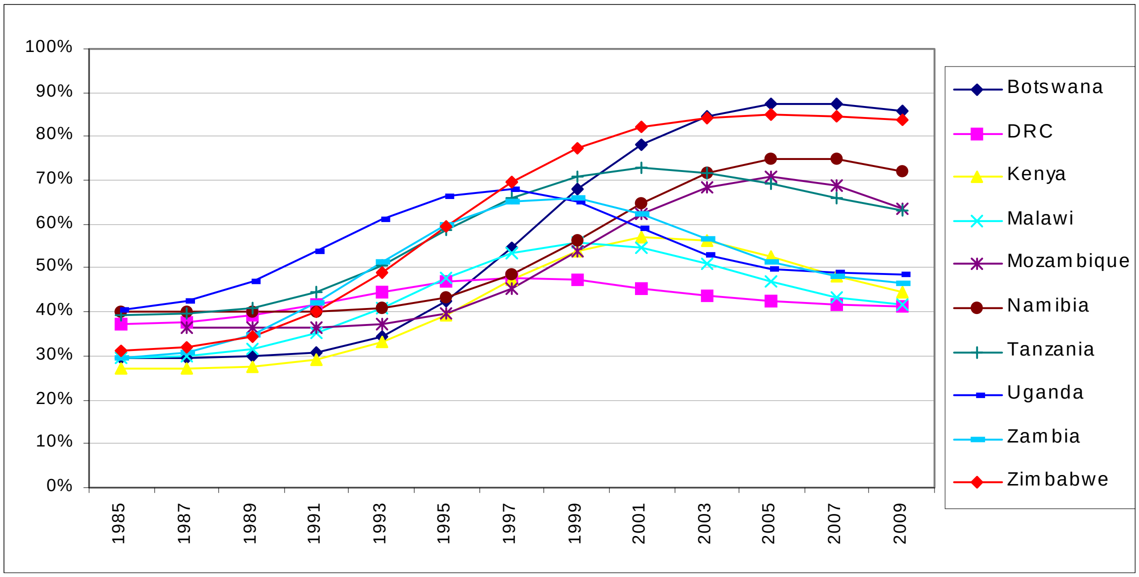

Figure 4: Country-specific adult mortality ($_{45}q_{15}$)

5.4 *Life expectancy*

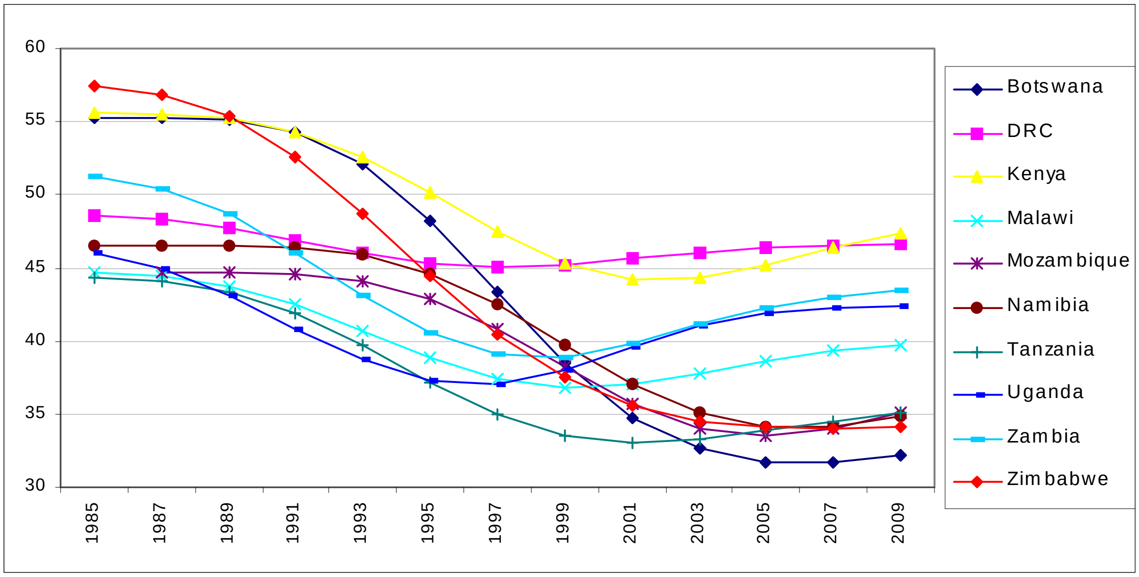

Figure 5: Country-specific life expectancy at birth

6. AN EXAMPLE OF BEHAVIOURAL CHANGE: UGANDA

As mentioned previously, the ASSA model does not explicitly allow for a change in sexual behaviour, once a particular point is reached. The ASSA AIDS model can, however, easily allow for changes in, inter alia, the number of unsafe sexual partnerships each female has per year (the model determines the number of male partnerships and sexual contacts on the basis that the total amount of heterosexual sex experienced by females must be the same as that experienced by males). In this section we examine to what extent the fall in prevalence in Uganda could be explained by a simple (and somewhat arbitrary) reduction in the number of sexual new sexual partners by some 50% over a 10-year period. However, before we do that it is interesting to consider to what extent the fall might be due to the natural course of the epidemic.

6.1 *Antenatal clinic data (urban centres – Kampala)*

Year of sentinel survey	Urban Centers		
	Kampala (Nsambya)	Kampala (Mulago)	Kampala (Rubaga)
1985	10.7		
1986	13.5		
1987	24.0		
1988	24.3	25.0	
1989	24.5	29.0	
1990	25.0	36.6	
1991	27.8		27.4
1992	29.5		29.4
1993	26.6	16.2	24.4
1994	21.8		16.5
1995	15.3		20.3
1996	14.6		14.8
1997	14.6		14.8
1998	13.4		14.2
1999	12.3		10.5

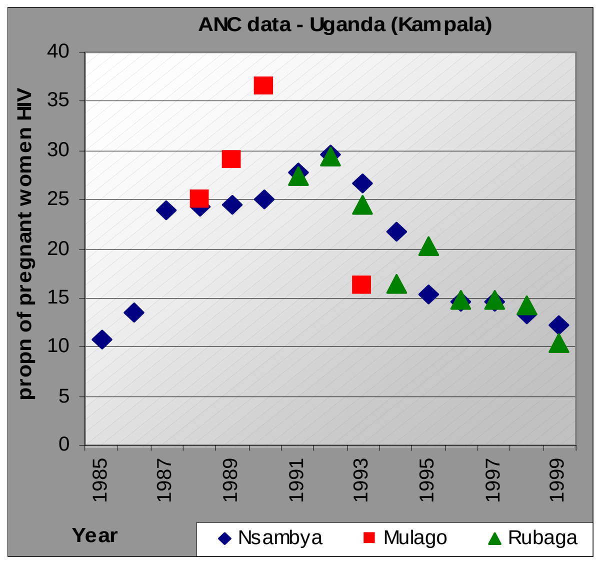

Figure 6: Antenatal clinic data (urban centres – Kampala)

As can be seen from the above ANC data, there is clear evidence of a rapid fall in prevalence levels from the early 1990s.

6.2 *Modelling sero-prevalence levels assuming no change in behaviour*

The curve below demonstrates the fit of the model to Uganda – assuming no change in behaviour. This shows that although the natural course of the epidemic would have resulted in a fall in prevalence, the observed drop in prevalences, particularly in the urban areas, is far more significant than explained by the natural course of the epidemic.

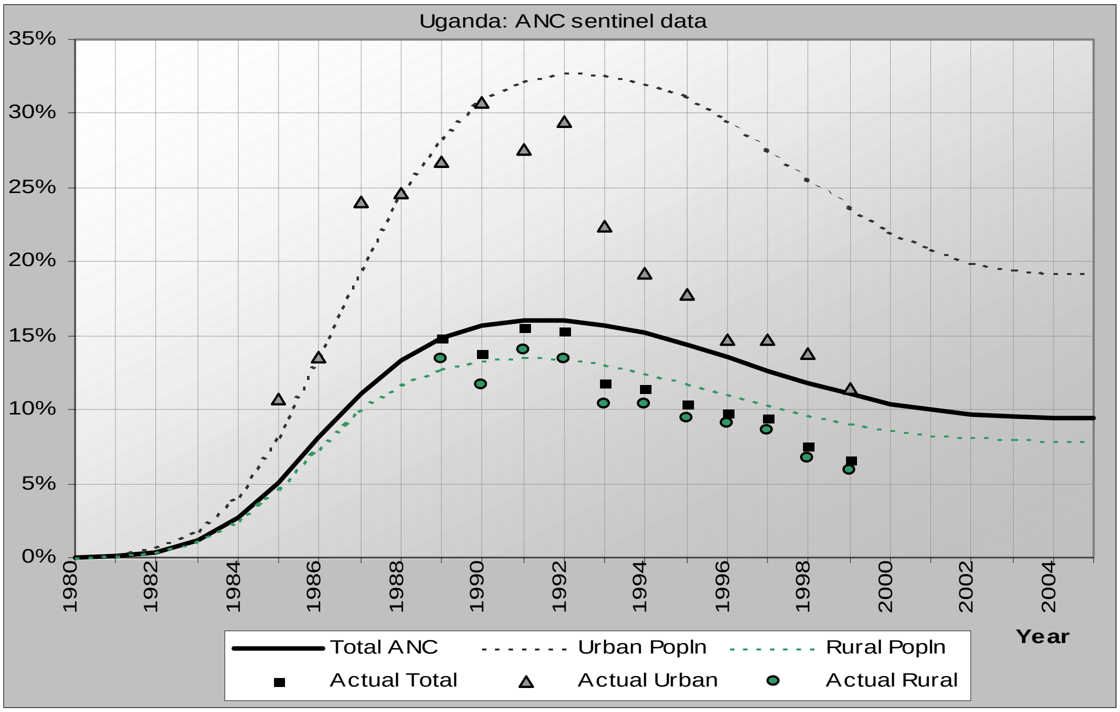

Figure 7: Uganda: assuming no change in behaviour

6.3 *Modelling of antenatal prevalence levels allowing for a change in behaviour*

The curve below demonstrates the fit of the model to Uganda allowing the number of new partners per annum to fall by between 50% and 67%, depending on risk group, over a 10-year period. As we can see, this simplistic assumption does not account for all the change (particularly in the urban population) but it could ‘explain’ a great deal of the drop in prevalence.

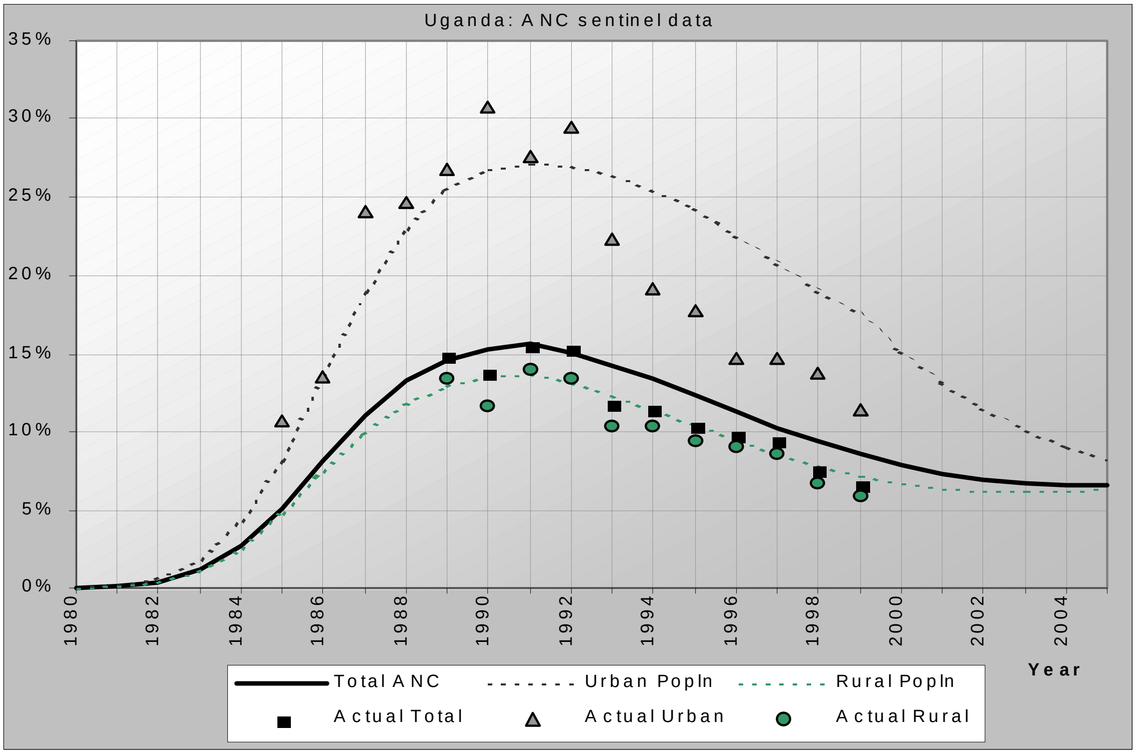

Figure 8: Ugandan prevalence levels allowing for a change in behaviour:

From the above projections we can draw the following conclusions:

(a) When modelling the HIV/AIDS epidemic one does need to allow for policy interventions, behavioural changes and anti-retroviral. Modelling these external influences is complex but Uganda clearly shows a need for such adaptations. We would recommend two separate algorithms depending on whether the change relates to sexual behaviour (such as in Uganda) or an external influence (such as Botswana, where the government has just recently announced that they plan to provide anti-retroviral therapy to all of its citizens). If the change is behavioural then it may be best to cater for the change via a ‘trigger’. Any external change would probably be best handled by a discrete change to survival curves, mother-to-child transmission probabilities, etc.

(b) The most significant change in behaviour appears to have occurred in the urban centres. Much of the downturn in the rural prevalence levels could be explained by the death of individuals infected in the early 1980s. Most of the population live in rural districts, hence overall the total projected population in 2010 with and without the behavioural modification, changes from 27.2m to 27.4m. Although this may not seem significant, if the model is correct then approximately 200,000 individuals will be saved from dying of AIDS as a result of the change in sexual behaviour in the late 1980s and early 1990s!

7. DISCUSSION

7.1 *Quality of the data*

The data points for most countries are very scattered and even the progression of the weighted average rates for the countries as a whole does not follow a smooth curve making the fitting of the model a bit of a lottery.

The data requirements of the model have been based on the maximum available in South Africa and as such are fairly extensive. However, the proportion of the population with STDs, the level of condom usage and the age of partners can be fairly easily gauged by a successful demographic and health survey.

Data is poor but undoubtedly improvements can be made on what we have done to produce these initial fits. Of particular concern is the modelling of the urban-rural migration, the proportion of the population with STDs, the age distribution of partners and the level of condom use.

7.2 Results

Despite the fact that this work is exploratory at the moment there are a number of observations one can make about the results:

- Southern Africa, as represented by Zimbabwe and Botswana are suffering a significantly worse epidemic than the rest of sub-Saharan Africa, as represented by the other countries, in particular the DRC.
- The prevalence curve experienced by Uganda is not apparent in other countries, where the observed prevalences to date can be tracked without assuming change in behaviour.
- Despite the relatively low levels in the non-Southern African countries life expectancy in half of the countries will fall below 35 years in the next 10 years.
- It is interesting to compare these results with those of others working in the field. Salomon and Murray (2001) attempted to model antenatal prevalences for four sub-Saharan countries, two of which, Botswana and Zimbabwe, were included in this exercise. Their results for Botswana were very similar to ours. However, they got very different results to us for Zimbabwe. Whereas our fit to the data would suggest that antenatal prevalence will reach about 35-36%, they estimate that it will barely reach 25% and they argue, further, that preliminary work to validate their results by considering a series of mortality studies suggests that their estimate might be too high. In order to investigate this further we compare in Figures 9 and 10 the estimate of extra AIDS mortality from our model against that derived by Feeney (1999).

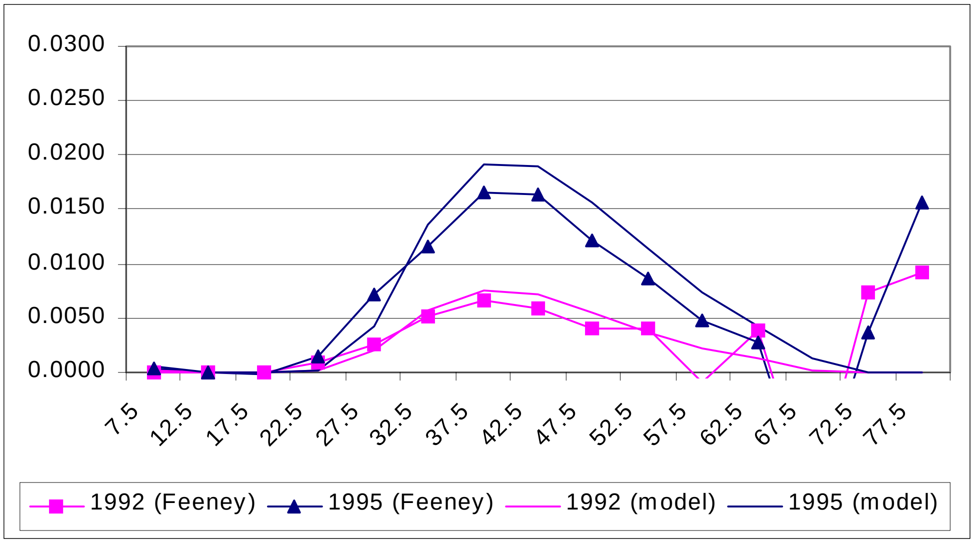

Figure 9: Comparison of AIDS mortality rates from the model against Feeney's estimates: Males

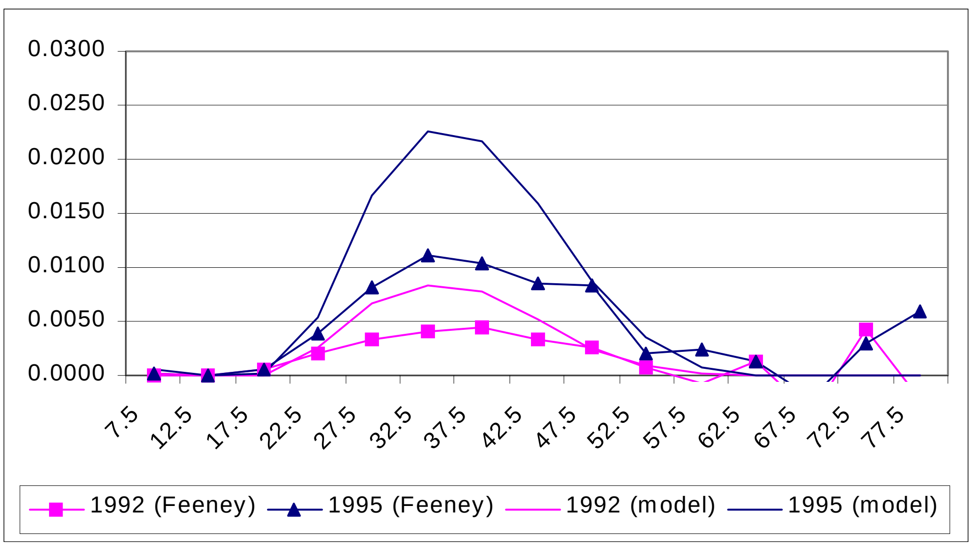

Figure 10: Comparison of AIDS mortality rates from the model against Feeney's estimates: Females

The first thing to strike us from these comparisons is how well the model reflects male AIDS mortality. However, although one might be tempted into thinking that the model exaggerates the extra AIDS mortality in females, this might not be the case, for Feeney's estimates of female AIDS mortality of half that of male AIDS mortality do not seem plausible given that more women are likely to be infected and infected earlier.

- Bearing this in mind it is interesting to contrast the estimates of Wils and Sandersen (2001) for Botswana, Mozambique and Namibia assuming no intervention or change in behaviour. Essentially they see rates rising monotonically in future however for Botswana they estimate current rates to be below 30%, rising to 32% by 2010. In the case of Namibia their estimate is already above 20% and rises to 25% by 2010. In the case of Mozambique their estimate of prevalence currently is similar to ours, however, they see it rising to over 21% by 2010.

7.3 Potential uses of the model

The model can be used, inter alia, to do the following:

- Test assumptions about the impact of behavioural changes, and with somewhat more difficulty, the impact of intervention designed to reduce transmission (e.g. MTCT), increase condom use, lower the prevalence of STDs, etc. For example, we were able to show that on the assumptions of the model, that even though it is quite possible that the natural course of the epidemic is that the prevalence levels drop after a point, with larger numbers of infected people dying, this does not explain the change in Uganda. On the other hand an effort to explain the change with a significant change in some of the parameters didn't completely explain the downward trend either suggesting that some of the assumptions underlying the model may need some modification.
- Provide estimates of mortality and fertility taking into account the effect of HIV/AIDS.
- Project population numbers. From the exploratory projection it is clear that it is only the Southern African countries that could see a levelling off or even fall in total population.

7.4 Further improvements to the model

The following is a list of improvements to be made to the model prior to release:

i. Replace the Gompertz fit to mortality rates with one using Beers six-parameter formula. In addition, improve on the interpolation of population numbers at individual ages.
ii. Allow for an improvement in non-HIV childhood mortality over time.
iii. Update the antenatal survey data with data from last year.
iv. Improve the quality of the data used.
v. Build in some form of behavioural change.
vi. Improve on the urban-rural migration procedure.

[i] The ASSA2000 and ASSA2000lite models can be downloaded from www.assa.org.za (The provincial versions have been delayed awaiting the release by the Department of Health of the of the more detailed results of the provincial antenatal surveys.)

[ii] Although relationships are obviously not confined to people of the same races, the proportion of such relationships was considered to be so small as to not materially affect the progression of the epidemic materially.

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APPENDIX A

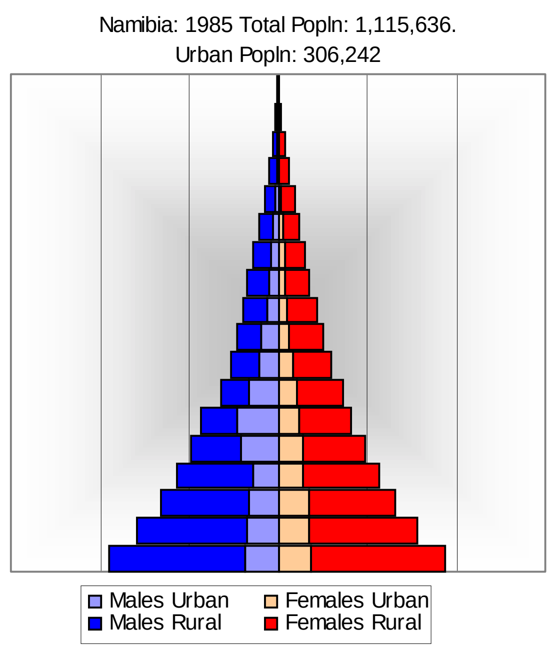
NAMIBIA

A.1.1 *Data Used for projection*

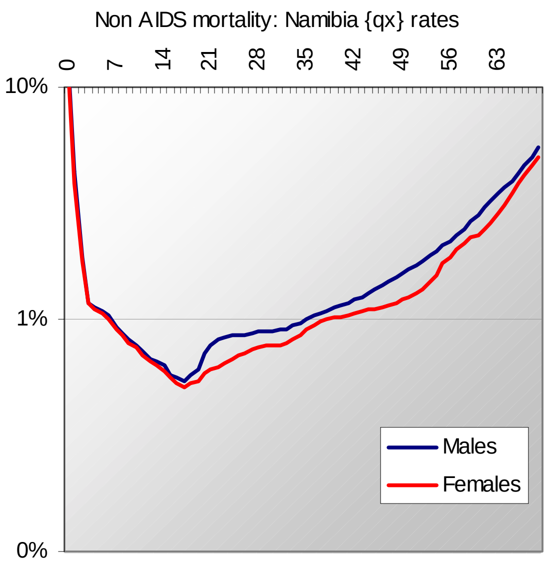
A1.1.1 *The initial population pyramid*

The table below summarises the initial population pyramid (total and urban populations) used in the projections:

Initial Population Pyramid (in 000's)				
Country	Namibia		Year	1981
Age Band	Total Population		Urban Population	
	Males	Females	Males	Females
0-4	83.6	81.9	16.1	15.2
5-9	69.5	68.7	14.6	14.8
10-14	57.9	57.9	13.6	14.3
15-19	49.6	49.6	11.7	12.2
20-24	42.2	42.2	17.3	11.9
25-29	37.2	35.6	19.3	10.0
30-34	27.3	32.3	14.2	9.1
35-39	23.2	26.5	9.3	6.8
40-44	19.9	22.3	8.0	5.7
45-49	17.4	19.0	5.3	4.5
50-54	14.9	15.7	4.6	3.7
55-59	12.4	13.2	3.6	3.6
60-64	9.1	10.8	2.3	2.4
65-69	6.6	8.3	1.4	1.5
70-74	4.1	5.8	0.5	0.7
75-79	2.5	3.3	0.3	0.4
80+	1.7	2.5	0.2	0.3
All ages	479.1	495.7	142.1	117.2
Total		974.77		259.29



Source: UN, 1999 and US Census Bureau, 2000



A1.1.2 *The non-AIDS mortality table*

Age Range	1000.qx-over range		1000.mx-over range		Fitted $\{q_x\}$ curve
	Males	Females	Males	Females	
0- 1	122.22	113.70	130.18	120.55	
1- 5	79.70	75.03	16.60	15.59	
5-10	47.07	45.86	9.64	9.39	
10-15	34.09	32.92	6.94	6.69	
15-20	28.28	26.39	5.74	5.35	
20-25	39.32	30.91	8.02	6.28	
25-30	42.84	36.29	8.76	7.39	
30-35	45.12	39.47	9.23	8.05	
35-40	51.93	47.49	10.66	9.73	
40-45	59.46	51.78	12.26	10.63	
45-50	70.67	56.33	14.65	11.59	
50-55	86.46	67.31	18.07	13.93	
55-60	111.15	95.88	23.54	20.14	
60-65	153.12	126.40	33.16	26.98	
65-70	212.91	194.45	47.65	43.08	
70-75	319.79	280.44	76.13	65.23	
75-80	458.14	412.74	118.85	104.01	
80+	627.48	571.52	182.87	160.04	

Source: US Census Bureau (2000)

A1.1.3 *The non-AIDS fertility*

The data used were as follows:

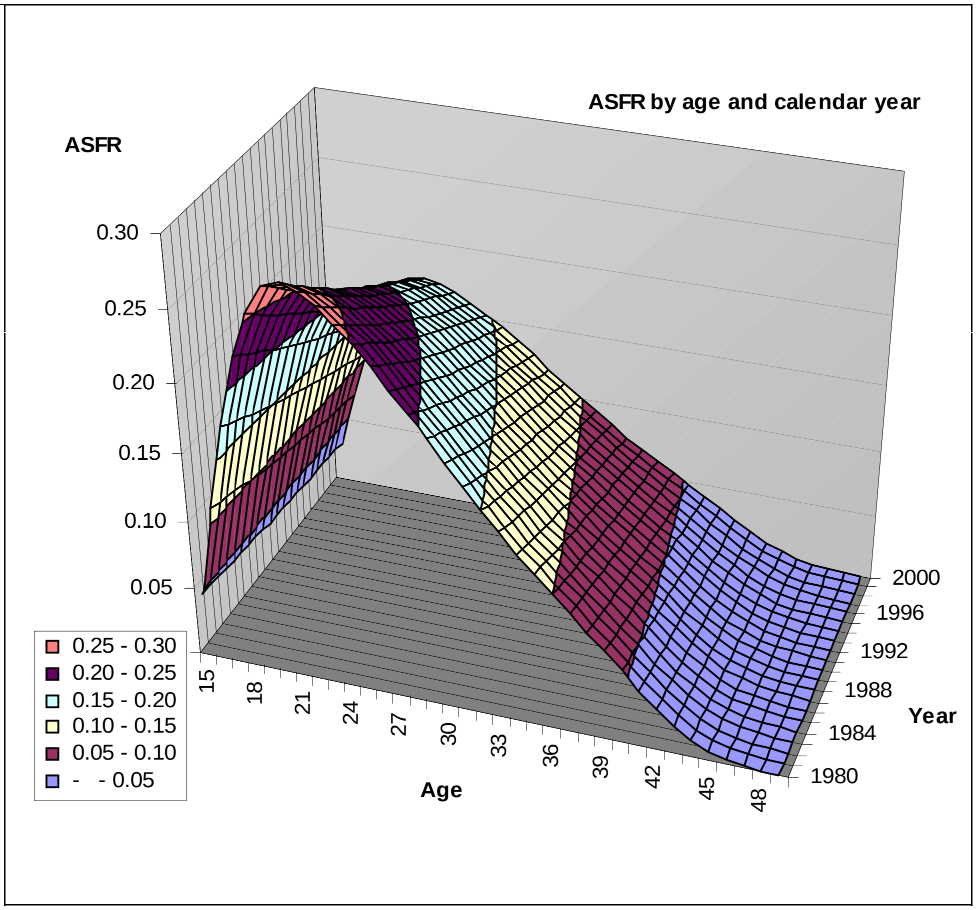
Total Fertility Rates		
Calendar years	Population Group	
	Total	Urban

Age specific Fertility Rate Weightings							
Year	15-19	20-24	25-29	30-34	35-39	40-44	45-49

1985-1990	5.40	4.32
1990-1995	4.85	3.88
1995-2000	4.35	3.48
2000-2005	3.90	3.12
2005-2010	3.50	2.80
2010-2015	3.10	2.48

1981	126.6	270.7	264.1	244.1	196.8	127.2	83.2
2000	64.9	161.3	175.7	153.1	114.5	65.8	24.7

Total Non-HIV Fertility Rates*	
1980	6.23
1981	6.08
1982	5.93
1983	5.79
1984	5.66
1985	5.52
1986	5.39
1987	5.26
1988	5.14
1989	5.02
1990	4.90
1991	4.78
1992	4.67
1993	4.56
1994	4.45
1995	4.35
1996	4.24
1997	4.14
1998	4.04
1999	3.93
2000	3.83



*Source: US Census Bureau (2000)

A1.1.3 *ANC Sentinel data*

The model is calibrated separately for urban and rural regions. The table below summarises the sentinel data used.

Urban Region	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Windhoek								4.2	5.5	6.8	11.4	16	19.5	23		
Walvis Bay														29		

Rural Region	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Rundu								4.1	6.25	8.4	8.4	8.4	18.1	14		
Katima Mulilo								13.7	19.1	24.5	24.35	24.2	25.7	29		
Otjiwarongo								1.9	5.4	8.9				16		
Swakopmund								2.9	5.1	7.3	12.35	17.4	16.2	15		
Keetmanshoop								3.4	5.9	8.4				7		
Opuwo								3.3	2.35	1.4	2.55	3.7	4.85	6		
Gobabis								1.3						9		
Onandjokwe										8.2	12.8	17.4	19.2	21		
Andara										2.1	6.3	10.5	17.3	16		
Engela										6.9	12.2	17.5	17.25	17		
Nyangana										6	5.65	5.3	6.8	10		
Nankudu													9.8	13		
Oshakati								3.6	8.9	14.2	18.3	22.4	28.2	34		

Source: HIV/AIDS Surveillance Data Base, US Census Bureau, June 2000

A1.2 *Key Assumptions*

A1.2.1 *Migration*

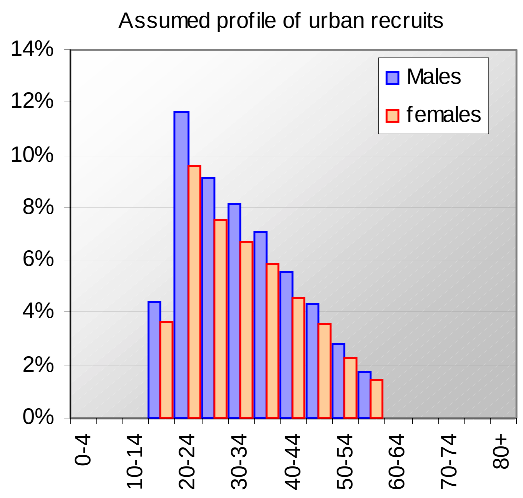
Data on migration are difficult to find or derive. For the purpose of this paper we have assumed that there is no net international migration. Urbanization has been explicitly modelled in the following manner:

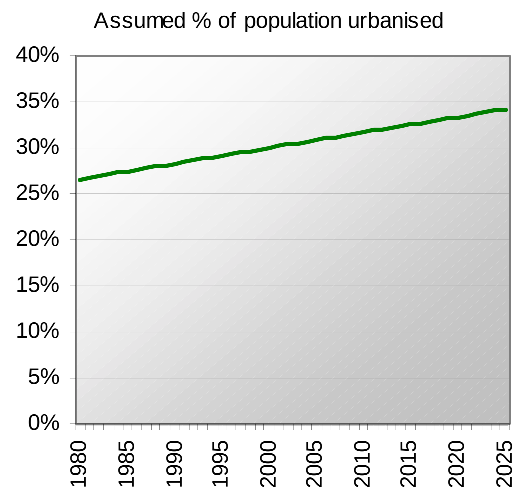
1. Based on two point estimates of the percentage of the population that was living in the urban centres we fitted a logarithmic curve to estimate the proportion of the population that is urbanized at any point in time. From this curve we were able to derive the urban population at each point in time.
2. Based on the actual urbanized population at the start of the investigation, we derived a profile (by age and sex) of recruitments into the country's urban centres from the rural regions.

These assumptions are summarised in the table below:

% urbanized from US Census Bureau		
Year	Urban Ratio	Comments
1970	24.9%	From US Census Bureau
2000	30.0%	Assumptions

The number of net urban recruits was distributed by age according to the distribution below:

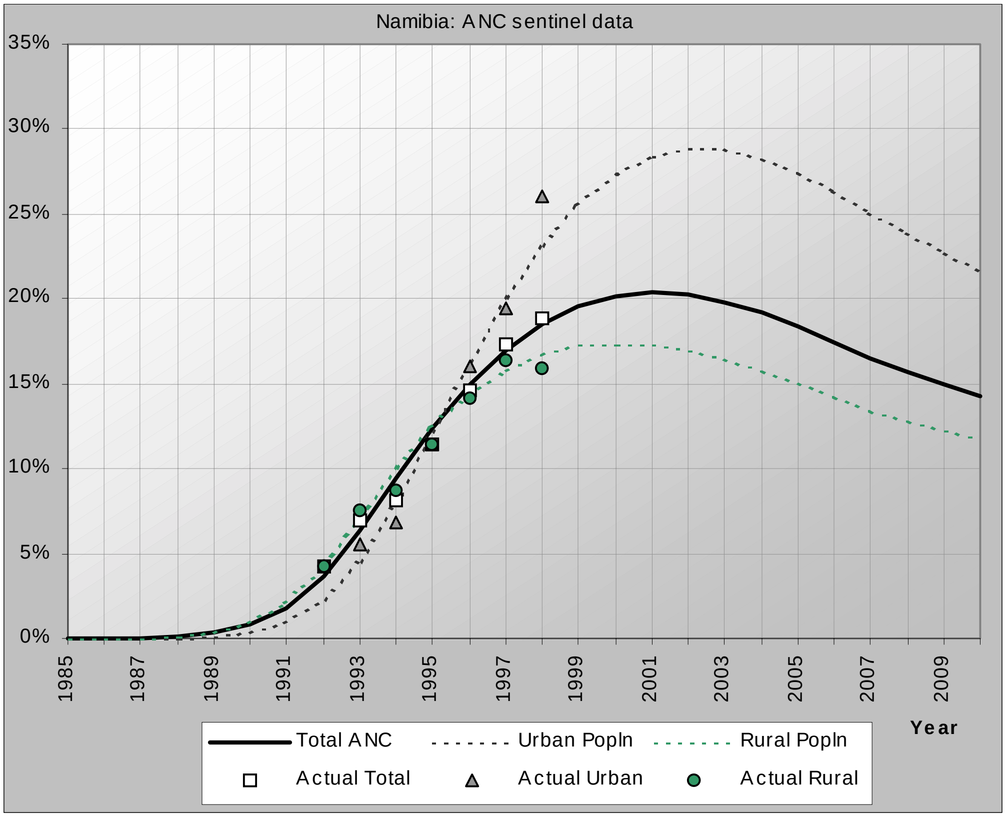




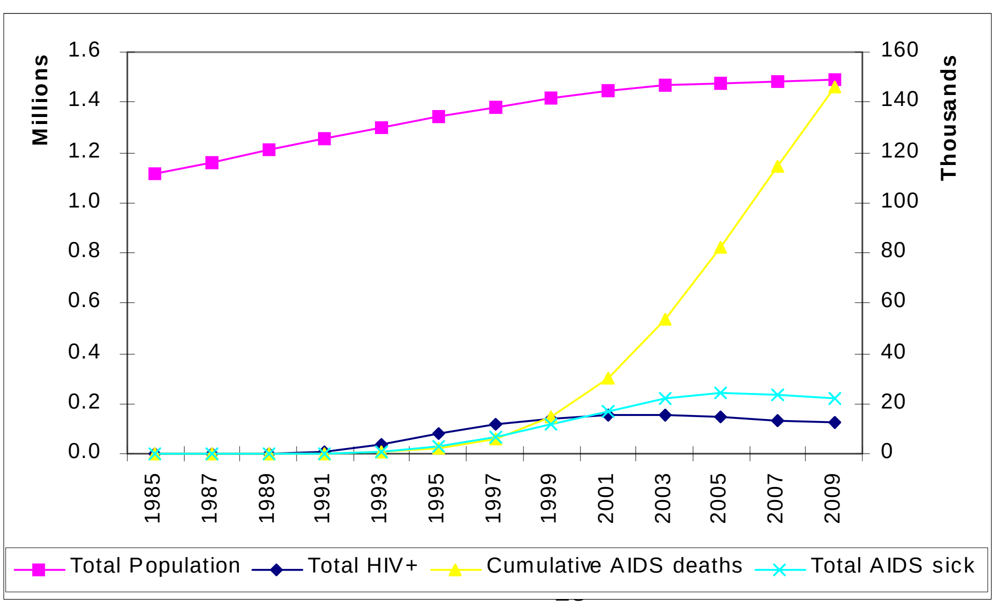
A1.3 *Results*

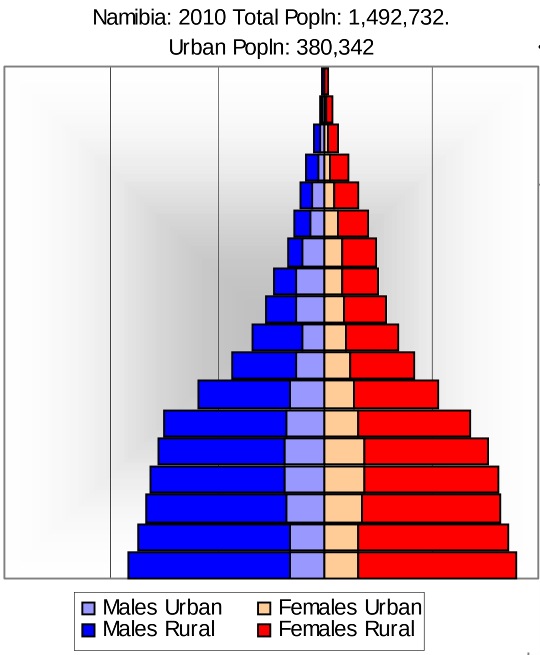
A1.3.1 *Comparison of modeled ANC data to actual data*

The curve below summarises the actual and modelled ANC sero-prevalence levels:

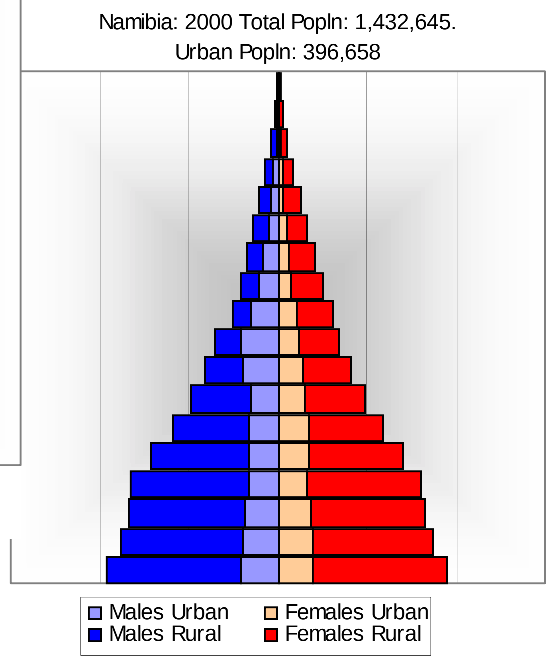


A1.3.2 *Key Statistics: Total Population, Cumulative AIDS deaths, Total HIV+, Total AIDS sick*

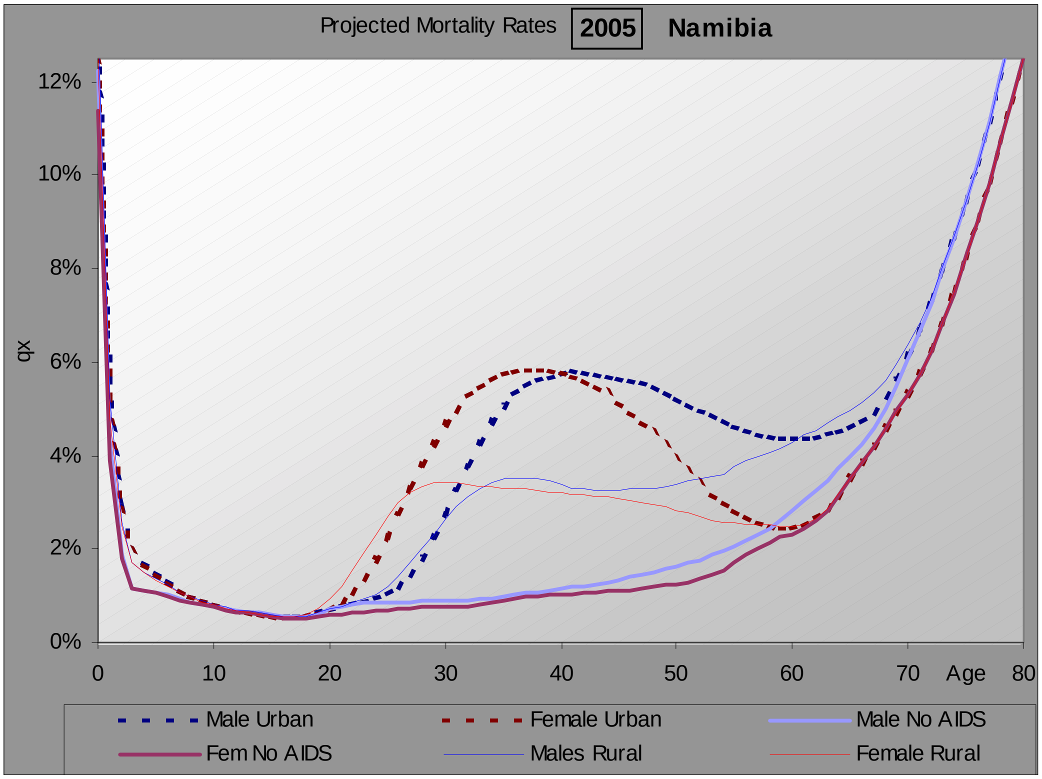




.3.2 *Population pyramids over time*



A1.3.3 *Mortality Rates in 2005*

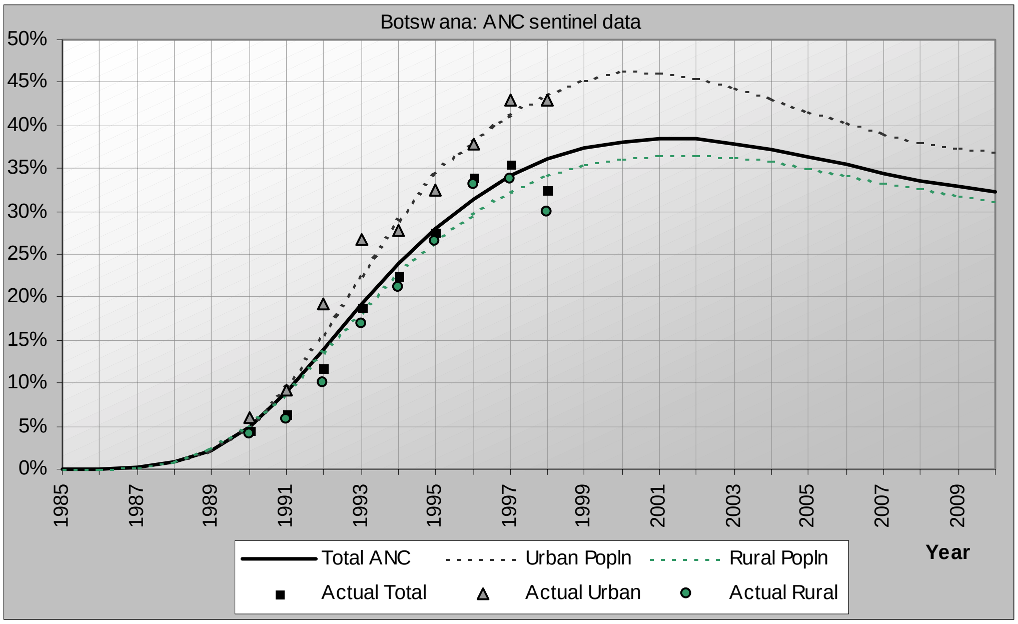


APPENDIX B

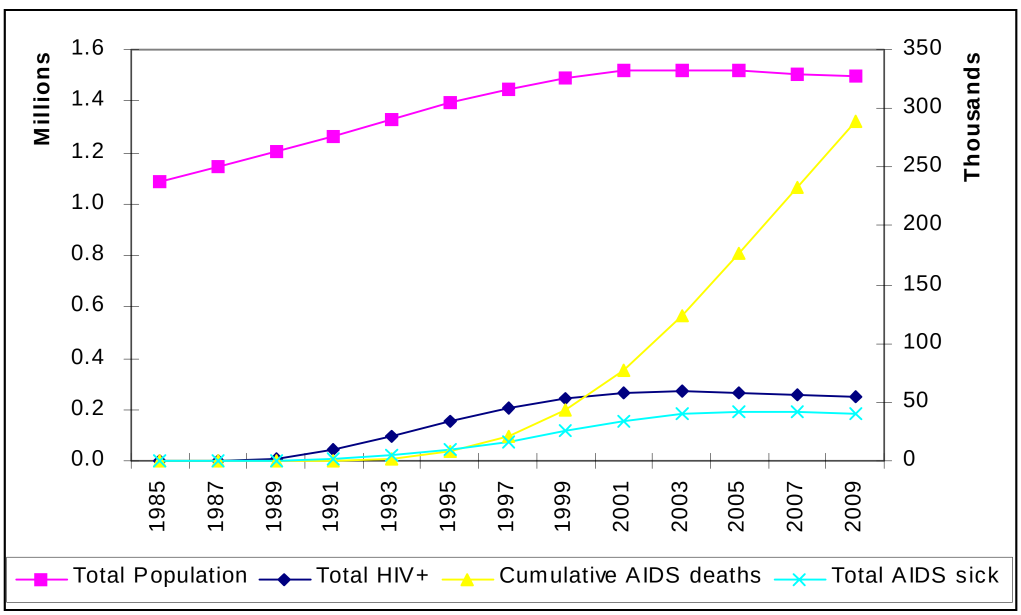
OTHER SUB-SAHARAN COUNTRIES

B1 *Botswana*

B1.1 *Comparison of modelled results (pregnant HIV+ women) to ANC sentinel data*

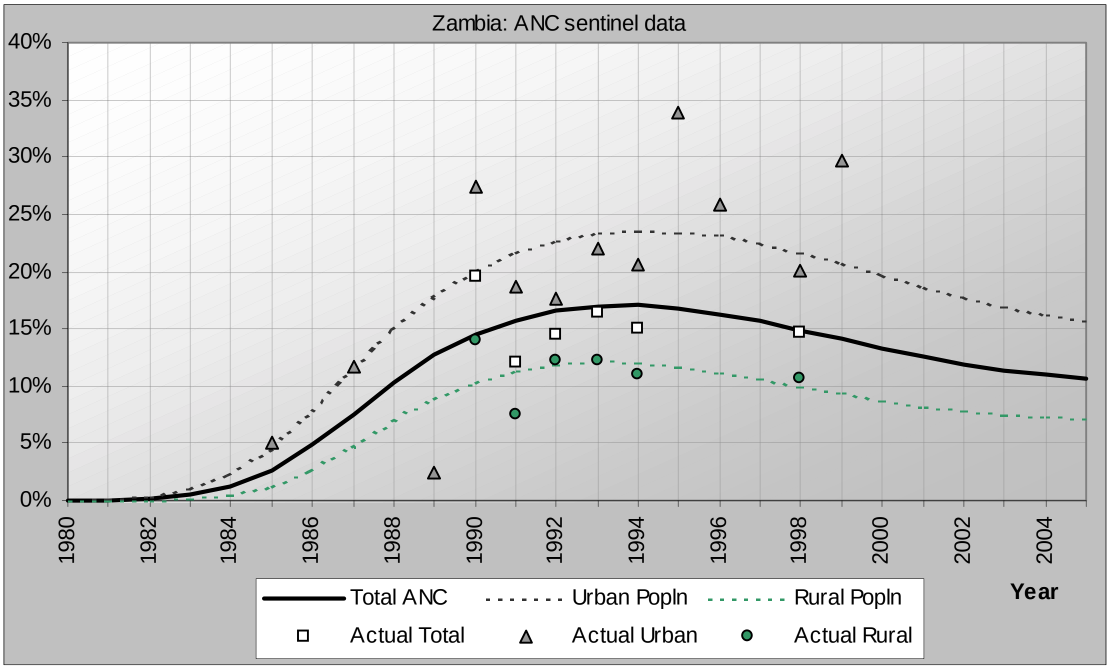


B1.2 *Key Statistics: Total Population, Cumulative AIDS deaths, Total HIV+, Total AIDS sick*

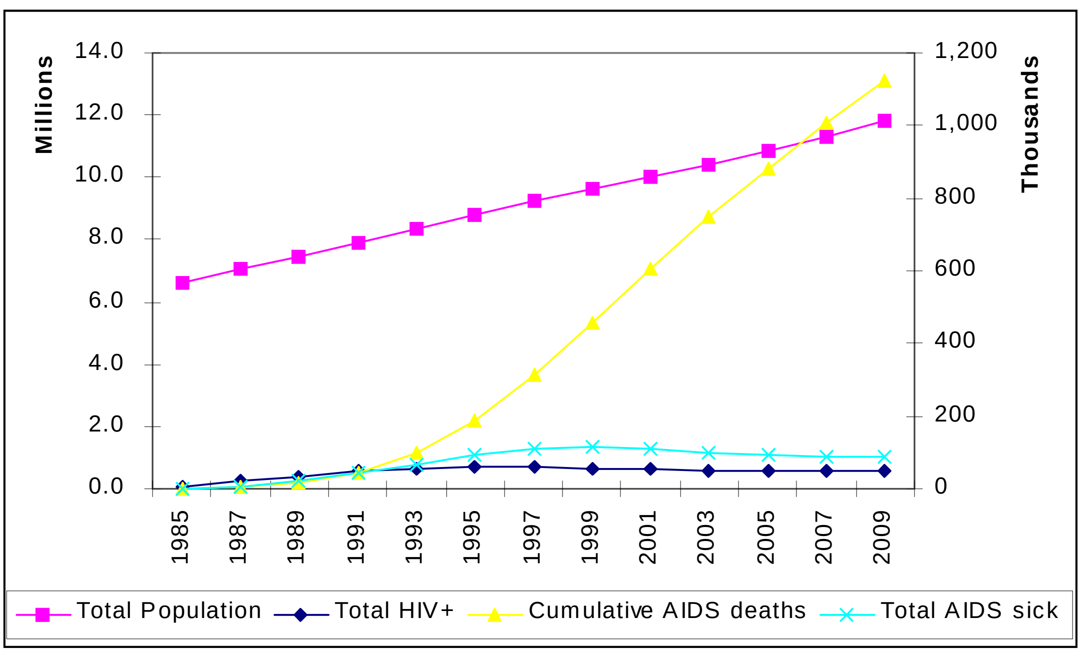


B2 *Zambia*

B2.1 *Comparison of modelled results (pregnant HIV+ women) to ANC sentinel data*

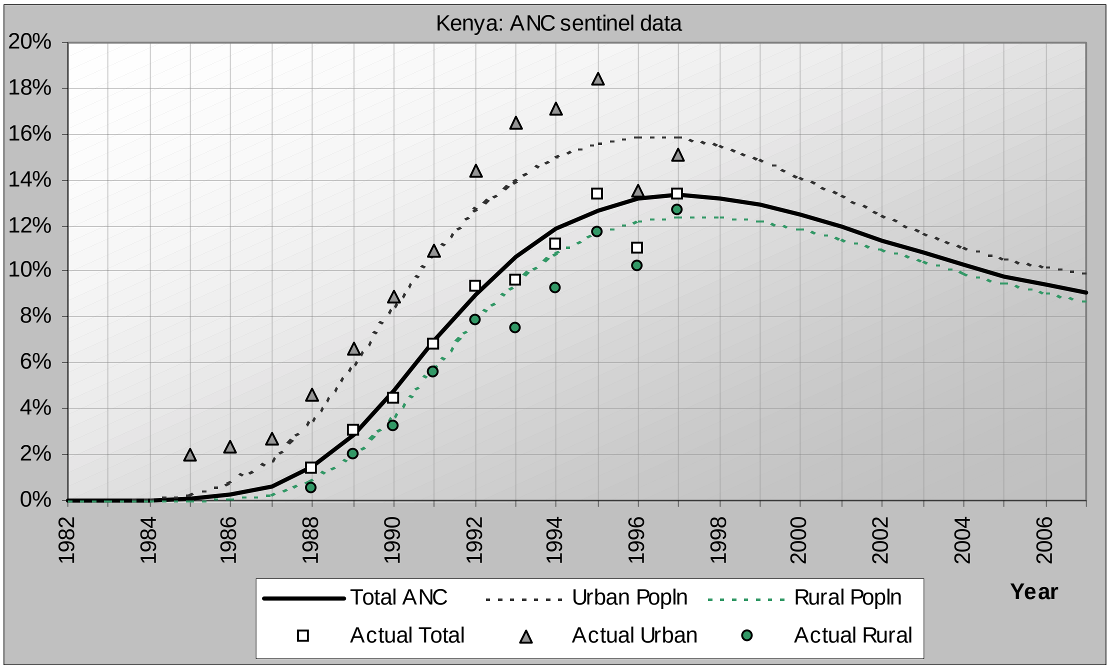


B2.2 *Key Statistics: Total Population, Cumulative AIDS deaths, Total HIV+, Total AIDS sick*

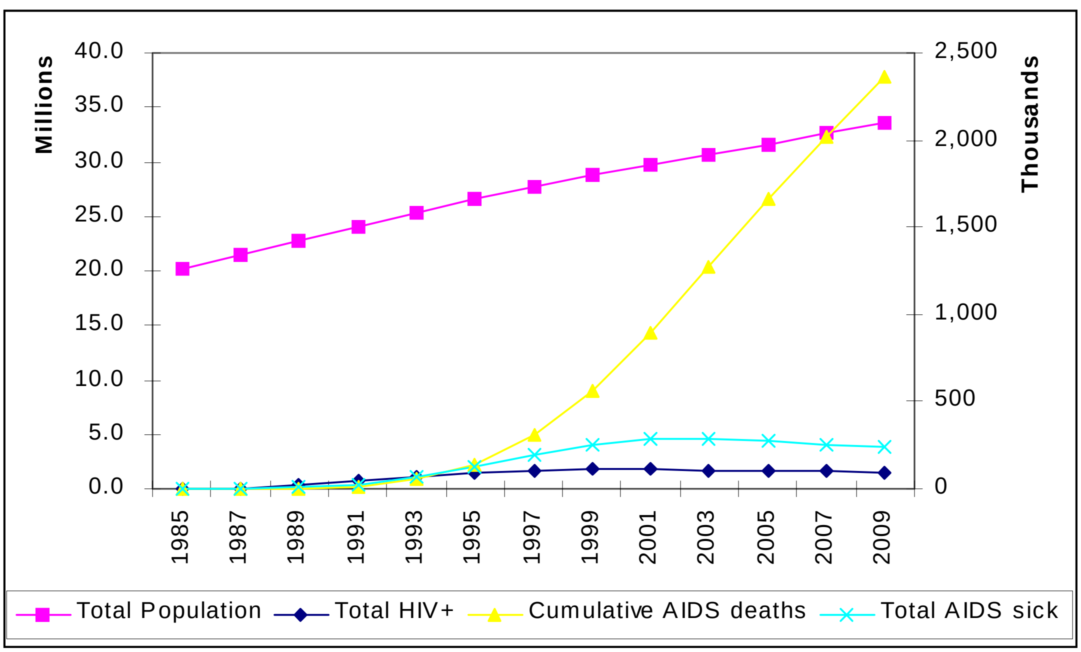


B3 *Kenya*

B3.1 *Comparison of modelled results (pregnant HIV+ women) to ANC sentinel data*

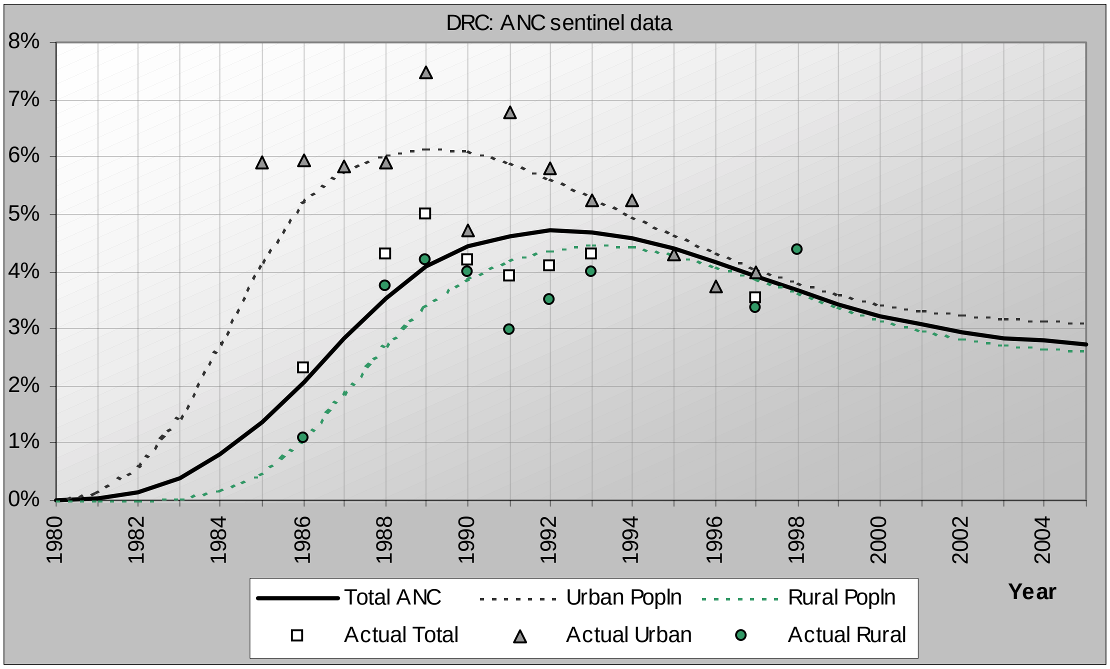


B3.2 *Key Statistics: Total Population, Cumulative AIDS deaths, Total HIV+, Total AIDS sick*

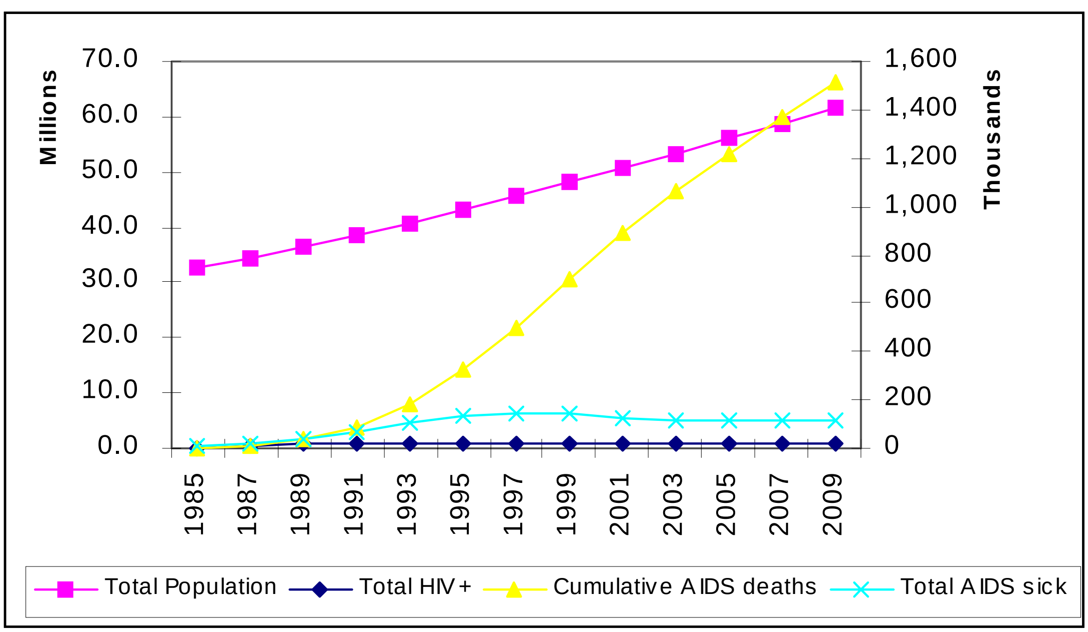


B4 *DRC*

B4.1 *Comparison of modelled results (pregnant HIV+ women) to ANC sentinel data*

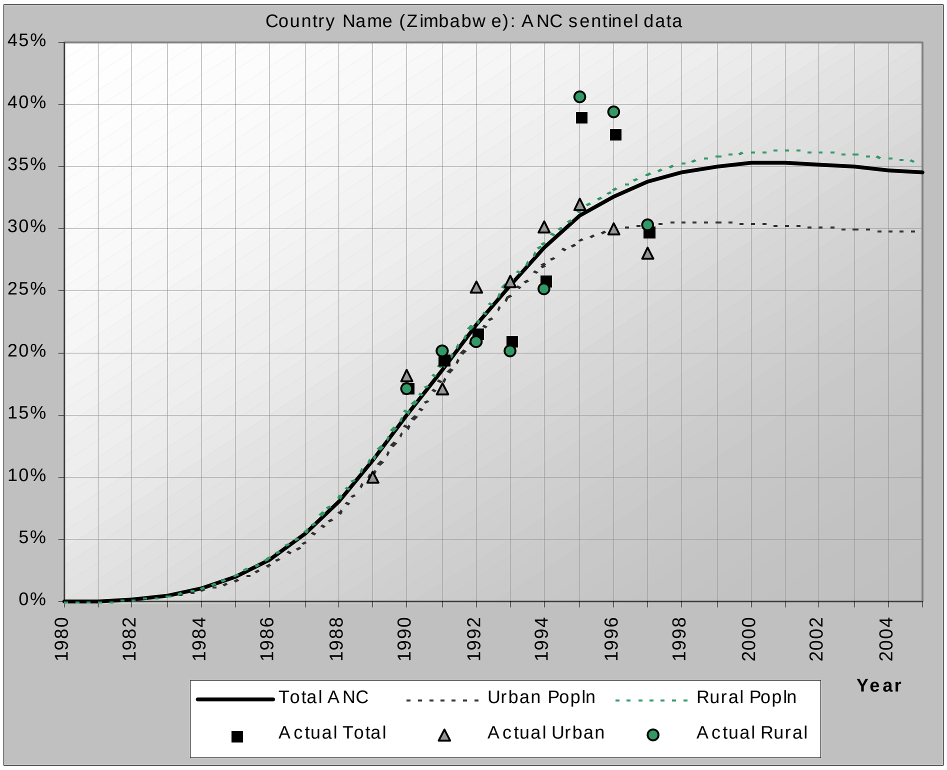


B4.2 *Key Statistics: Total Population, Cumulative AIDS deaths, Total HIV+, Total AIDS sick*

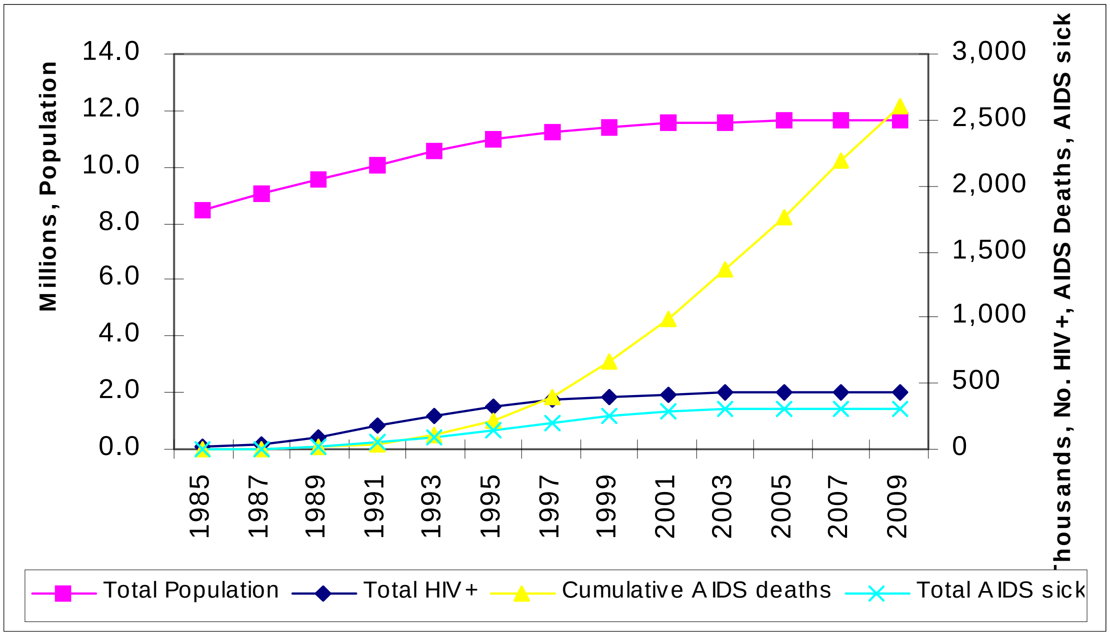


B5 *Zimbabwe*

B5.1 *Comparison of modelled results (pregnant HIV+ women) to ANC sentinel data*

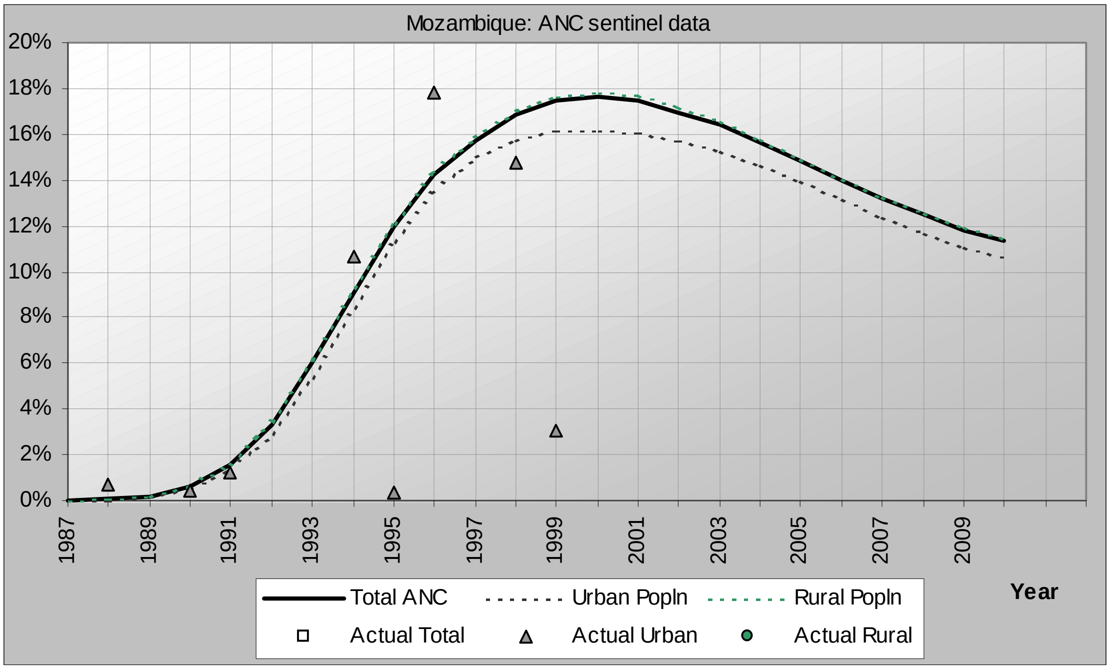


B5.2 *Key Statistics: Total Population, Cumulative AIDS deaths, Total HIV+, Total AIDS sick*

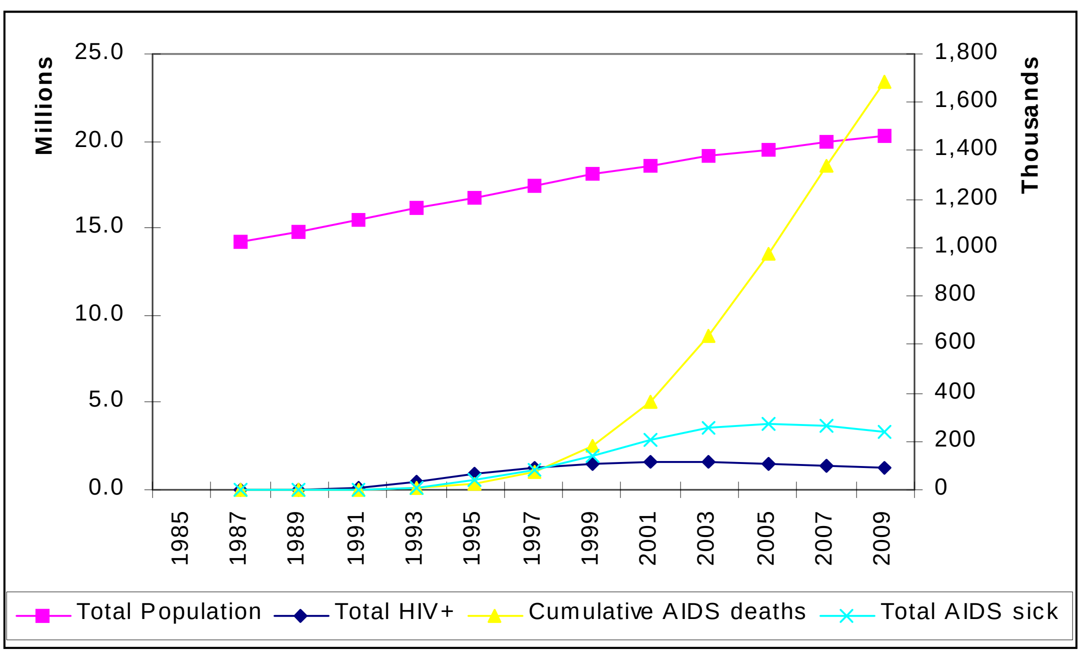


B6 Mozambique

B6.1 *Comparison of modelled results (pregnant HIV+ women) to ANC sentinel data*

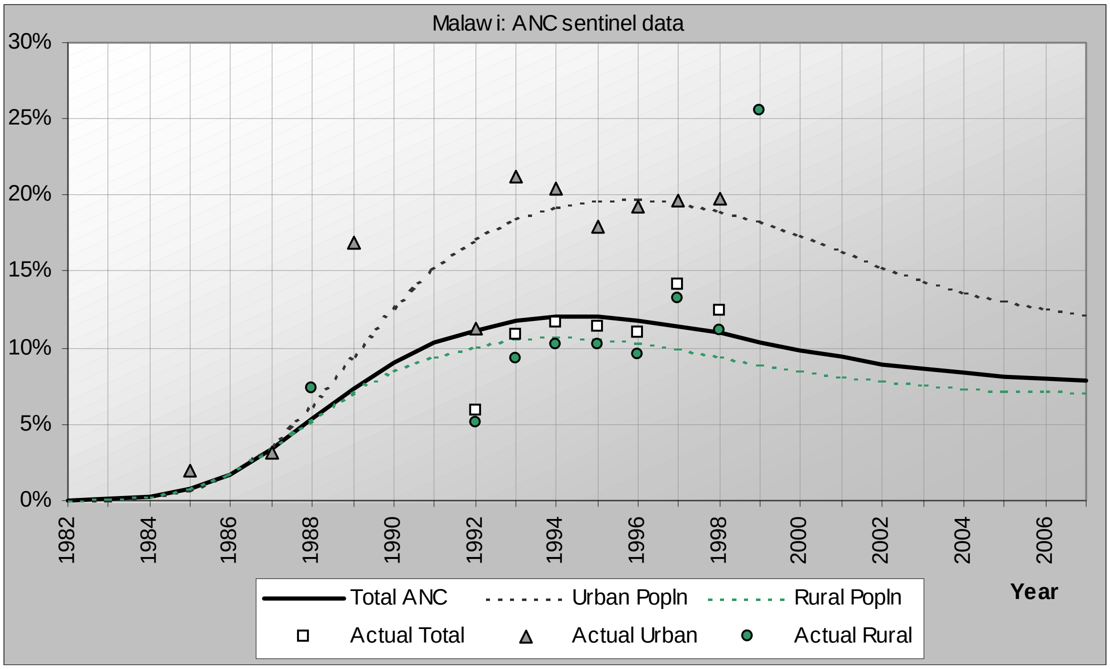


B6.2 *Key Statistics: Total Population, Cumulative AIDS deaths, Total HIV+, Total AIDS sick*

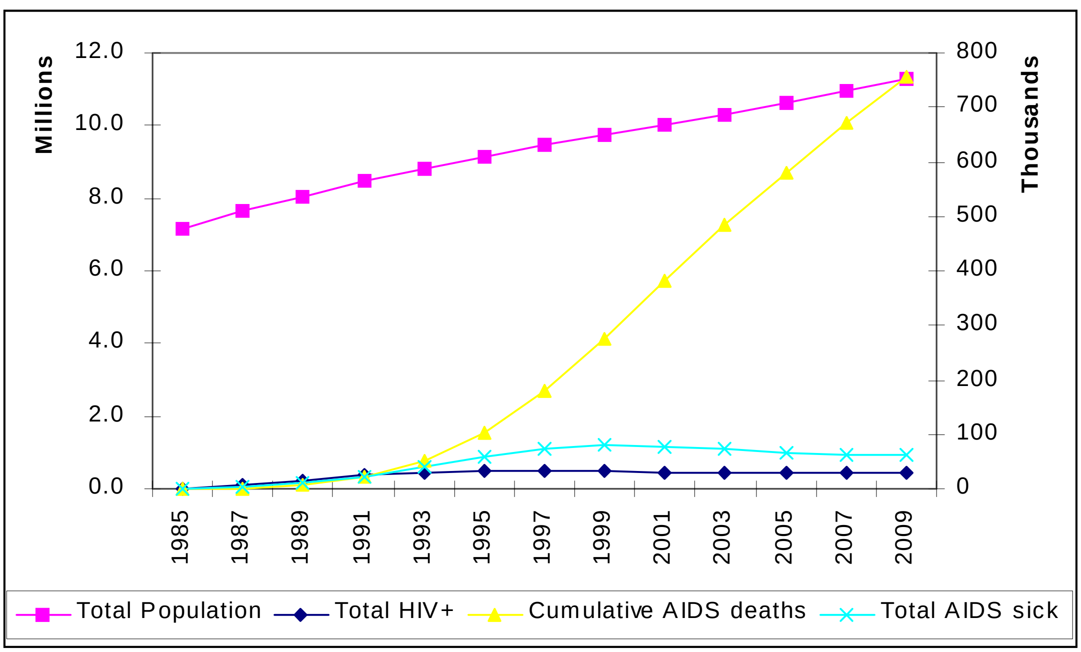


B7 *Malawi*

B7.1 *Comparison of modelled results (pregnant HIV+ women) to ANC sentinel data*

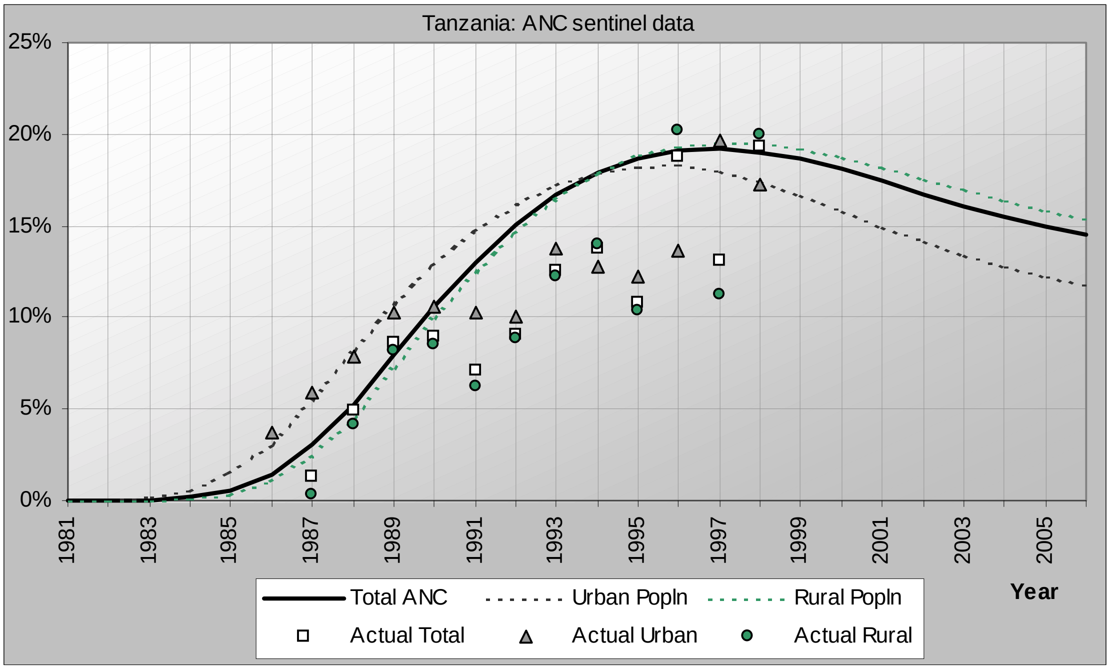


B7.2 *Key Statistics: Total Population, Cumulative AIDS deaths, Total HIV+, Total AIDS sick*

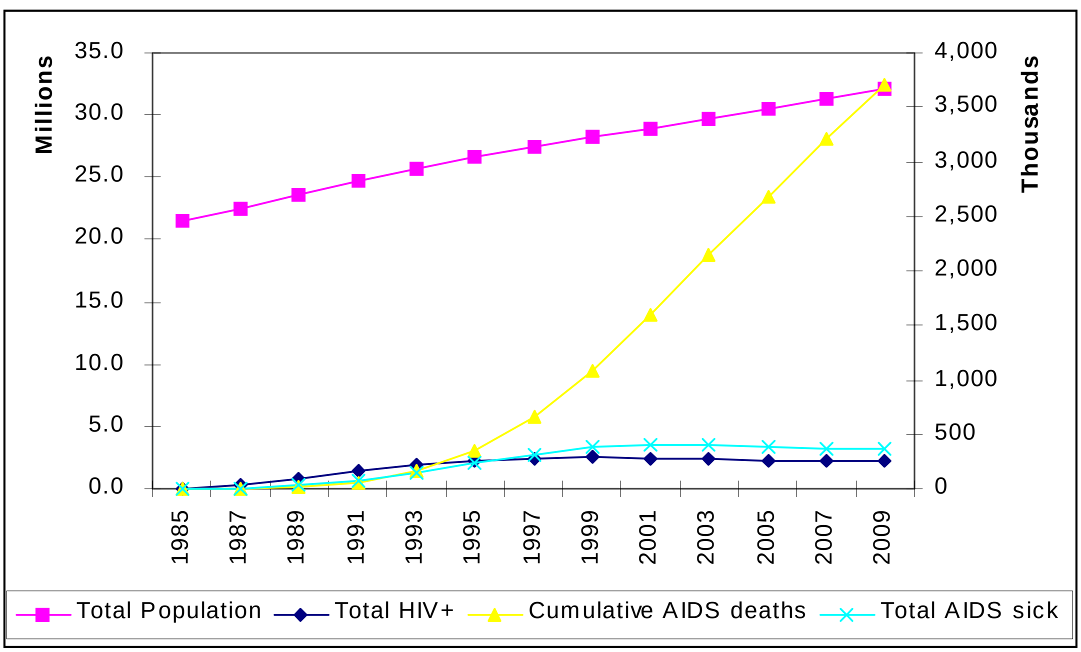


B8 *Tanzania*

B8.1 *Comparison of modelled results (pregnant HIV+ women) to ANC sentinel data*



B8.2 *Key Statistics: Total Population, Cumulative AIDS deaths, Total HIV+, Total AIDS sick*



APPENDIX C

A BRIEF DESCRIPTION OF THE ASSA2000 MODEL

Essentially the model models the demographic impact of HIV/AIDS on the national population by assuming that the population, as a result of its history if nothing else, can, for the purpose of modelling heterosexual activity and demographic projection, be divided into four ‘population groups’, which are assumed to have different proportions of commercial sex activity (PRO group), STDs and risky behaviour (RSK), different levels of condom usage and different age distributions of partners, and of course, different non-AIDS mortality and fertility and patterns of migration.

Each of these population groups (at the start of the epidemic and those turning 14) is assumed to be further split into four risk groups depending on the rate of transmission over a year (namely a small very high risk group of sex workers and clients, a much larger group assumed to be at similar risk as those with STDs, an even larger group who are at risk because of their sexual behaviour and a similarly sized group who are assumed never to be at risk). The model assumes a median term to death of 11 years from HIV/AIDS mortality and effectively two years for infants born with the virus. It for those aged 14-24 and 10 years for those older than this when they seroconverted, and also allows for the impact of the virus on fertility. No behavioural changes or interventions are specifically allowed for in the model, although these can be easily be allowed for, within the constraints of the structure of the model, when running the model.

The structure of the model is illustrated in the figure on the next page.

The model has been calibrated to reproduce the prevalence results of the national antenatal survey up to the 2000, the patterns of deaths from the Department of Home Affairs for each of the three years ending mid-2000, and to produce a population of 42.2 million as at the date of the 1996 census. It further assumes a net immigration, increasing rapidly from the early 1990s to 1996 and then assumed to decrease to zero over the following 30 years.

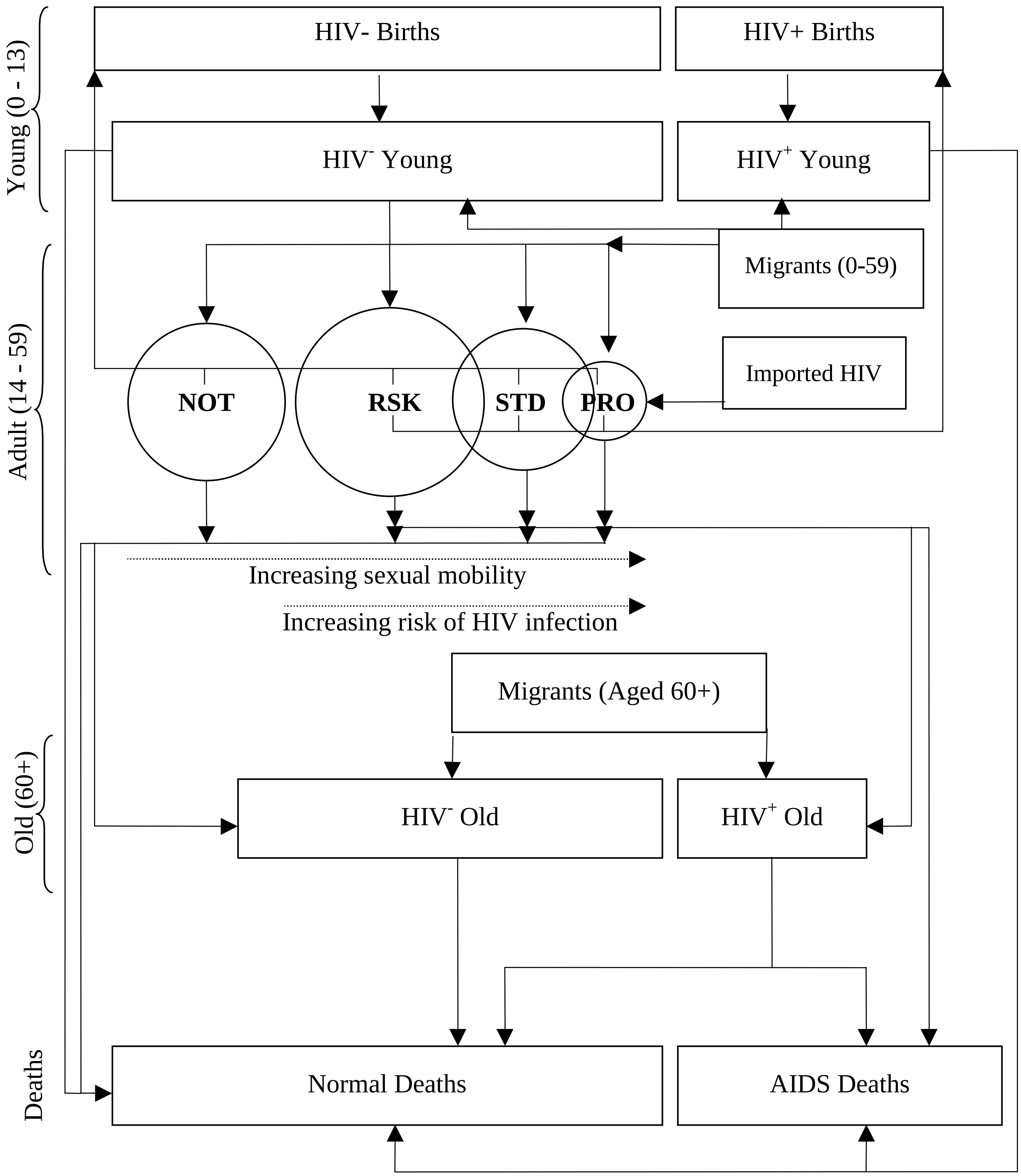


Figure E.1: A schematic diagram of the model structure underlying ASSA2000