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AIDS in Botswana: Evaluating the general equilibrium implications of healthcare interventions

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Abstract

This paper reports an analysis of the effects of health care interventions designed to reduce the impacts of the HIV/AIDS epidemic on the Botswana economy. The analyses were conducted using a recursive dynamic computable general equilibrium model for Botswana within which was embedded a compartmental epidemiological model. The health care interventions examined are reductions in other sexually transmitted diseases (STDs) that reduce the probability of HIV transmission and a mass media health education programme that reduces the number of new sexual partnerships being formed. While the policy scenarios examined are, necessarily, somewhat stylised, the results indicate both the devastating adverse effects of the epidemic and the substantial potential benefits of the interventions. Without interventions disposable household incomes per capita are up to 50 percent less than they would have been in 2020, but with these interventions the adverse effects of the epidemic are more than halved.

Keywords: HIV/AIDS; Computable General Equilibrium; Healthcare
JEL classification:

1. Introduction

Over 27 million people in sub-Saharan are living with HIV/AIDS, and this burden is greatest in Botswana where the adult prevalence is around 36%. As well as the human cost, the epidemic is having profound effects on the economy through increased government expenditure and reduced labour productivity. The scale of the interventions required to tackle this problem are so great that they dwarf the national economy, thus raising fundamental issues around balance of payments, opportunity costs of health resources, labour shortages and factor prices. These effects reach beyond the conventional view of partial equilibrium economic evaluation; hence the additional information from a general equilibrium approach should be useful for policy makers.

The analyses are conducted using a 106 account computable general equilibrium (CGE) model of the Botswanan economy calibrated on the 1993/4 national accounts. The model is a recursive dynamic model for which the counterfactual solution replicates econometric predictions of GDP, investment and population under the assumptions of no HIV/AIDS and unchanged economic policies. The distinctive features of the model are the embedding of a compartmental epidemiological model that endogenises the impact of the epidemic upon labour supply in terms of mortality. The model simulations show profound effects of the HIV/AIDS epidemic on welfare caused by the erosion of the population.

The impacts of healthcare interventions are then introduced into the model. The direct costs of the interventions include both the material and skilled labour costs, while the direct benefits are manifest as the preservation of life. Because the costs and benefits of the interventions are endogenous the model shows the profound general equilibrium consequences; these are primarily manifested through a massive increase in the relative price of health care, substantial tax increases necessary to stabilise the government budget position and a sharp deterioration in the current account. These effects raise important issues in terms of the resourcing of interventions, especially when skilled labour is scarce, and indicate the high potential payoffs from targeting interventions at economically important groups. This information, which may be morally questionable, may be crucial for policy formulation.

The rest of the paper is organised as follows. The next section provides an overview of HIV/AIDS in southern Africa with some specific references to Botswana. In section 3 a compartmental epidemiological model is specified and explained and the processes of calibrating this model with Botswana data are detailed. The CGE model and data are described in section 4 while the policy experiments and results are reported in section 5. The final section offers some concluding comments and suggestions for developments.

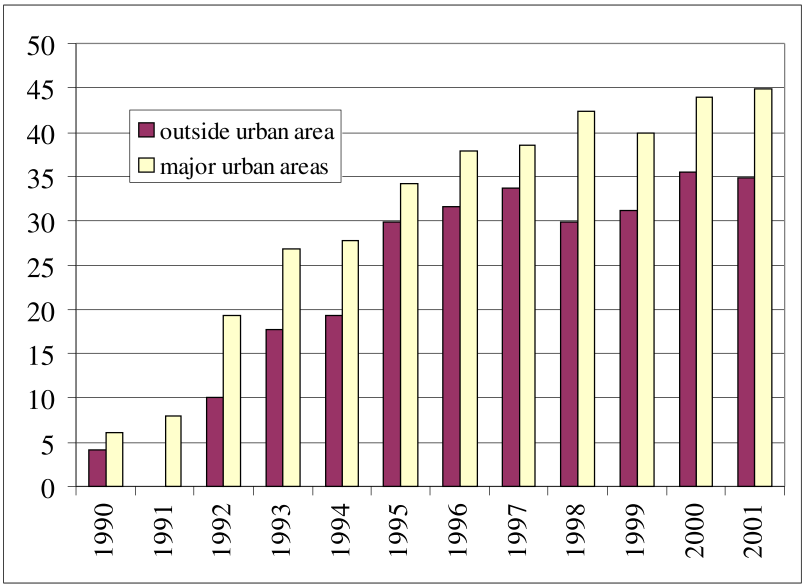
2. HIV/AIDS in southern African and Botswana

The latest UNAIDS figures (UNAIDS 2003) suggest that approximately 40 million people globally have HIV/AIDS, with 5 million newly infected in 2003. The worlds worst affected area is sub-Saharan Africa (SSA), where around 27 million people have HIV/AIDS. 10 million are young people (aged 15-24) and almost 3 million are children (under 15). Around 3.2 million people in SSA became infected in 2003.[1]

Within SSA the burden is greatest in Botswana where adult prevalence is estimated at 36%. This has increased from 10% in 1992. Life expectancy in Botswana was around 67 years in 1990 but is now around 47 years and is expected to fall to under 30 by 2010. Also during this same time frame it is estimated that 20% of all children in Botswana will be orphans. Over half of new cases of HIV infection in Botswana occur before the age of 25 and the rate among girls outnumbers that in boys by a factor of 2 or 3.

The most reliable data on HIV prevalence comes from the sentinel surveillance of anti-natal clinic attendees, which began in Botswana in 1990. Figure 1 plots the median prevalence rates calculated from this data collected at a number of sites across Botswana, both inside and outside major urban areas. The rapid spread of the epidemic is clear from these figures.

Figure 1 HIV Sentinel Surveillance Data (median prevalence (%) among pregnant women attending ANCs)



1 All figures in this section are taken from UNAIDS *AIDS Epidemic Update (December 2003)* and UNAIDS *Epidemiological Fact Sheet for Botswana (2002 Update)*

Botswana is relatively economically successful on the African continent, but nevertheless a large proportion of the 1.6 million population lives in poverty. It is one of the first African countries to move into second generation planning under the UNAIDS strategy and was the first to introduce a pilot programme offering free anti-retroviral treatment to around 7,000 people. In addition it has a well-established programme providing free Prevention of Mother-to-Child Transmission (PMTCT) treatments to pregnant women and has started intensive initiatives to enhance the sexual and reproductive health of young people. One of the main constraints on these interventions is a lack of trained healthcare workers to administer them. UNAIDS has recently argued that while Botswana has had some success in dealing with HIV/AIDS during its decade long response, the epidemic is continuing to gain ground.

3. The Compartmental Epidemiological Model

The epidemiological model is needed to describe the prevalence of HIV and AIDS over time within Botswana, so that the population effects of the epidemic can be introduced into the CGE model. The model also needs to be capable of simulating changes in the epidemic caused by changes in population behaviour brought about by policy interventions. Several distinct approaches are possible (Gail and Brookmeyer, 1998), however, a compartmental modelling approach was adopted as behavioural parameters are given explicit recognition in its formulation.

The model we developed is based around two distinct populations; high risk and low risk. This allows it to characterise epidemics with exponential growth (in the high risk population) in its early stages, followed by sub-exponential growth (in the general population). Both populations are then further sub-divided into those who are currently infected – the infecteds – and those who may become infected – the susceptibles. Expressions for the changes in the numbers infected and susceptible for each sub group between period t and (t+1) are then derived, based upon the numbers infected and susceptible in the previous period and a series of transmission parameters, i.e.,s

Susceptibles

$$S_r(t+1) - S_r(t) = -S_r(t)\{\lambda_s + (1-\lambda_s)\pi_r + (1-\lambda_s)(1-\pi_r)\gamma_r(t)\} + C_r$$

Infecteds

$$I_r(t+1) - I_r(t) = S_r(t)\{(1-\lambda_s)(1-\pi_r)\gamma_r(t)\} - I_r(t)\{\lambda_i + (1-\lambda_i)\pi_i\}$$

where

r = risk group, either 'high' or 'low';
S_r = Number of susceptibles in risk group r;
I_r = Number of infecteds in risk group r;
λ_s = Annual death rates in susceptibles;
λ_i = Annual death rates in infecteds;
π_r = Emigration rate in risk population group r;
C_r = Number of new susceptibles who immigrate each year into risk group r;
$\mu_{r,r}$ = Number of new sexual relationships per year by risk group individuals;
$\beta_{r,r}$ = Chance that HIV is transmitted during sex between risk group individuals;

and

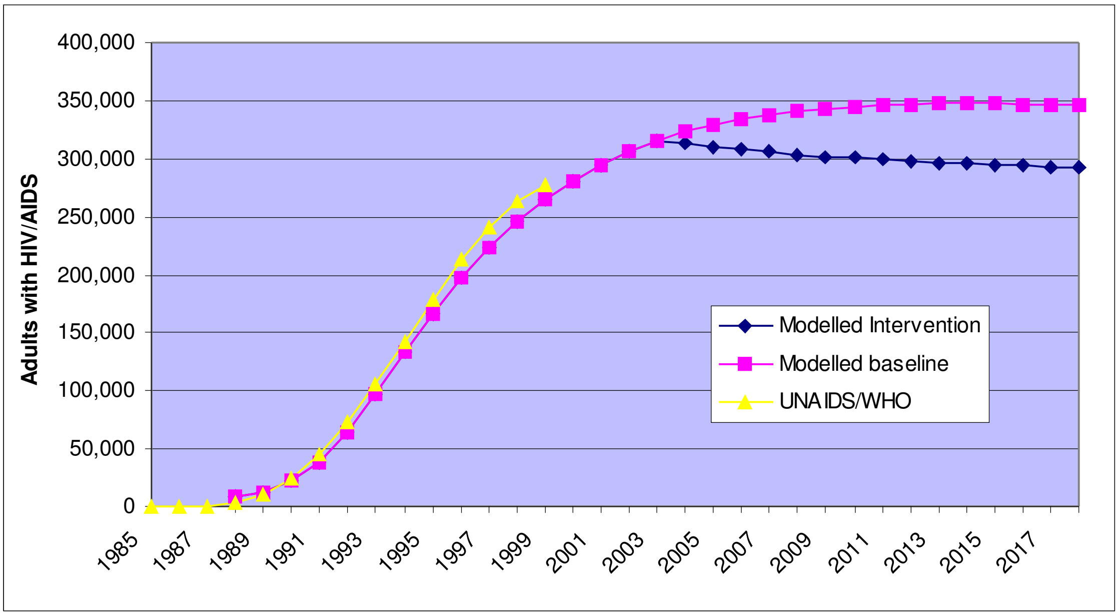
$$\gamma_r(t) = 1 - \exp\left\{-\sum_r \mu_{r,r}\beta_{r,r}\rho_r(t)\right\}$$ –Transmission rate in risk groups at time t

$$\rho_r(t) = \frac{I_r(t)}{(S_r(t) + I_r(t))}$$ –Prevalence in risk groups at time t

This model is then calibrated to follow the UNAIDS estimates for HIV/AIDS prevalence in Botswana. Whilst there is a growing body of research describing death rates, sexual activity and transmission probabilities in sub-Saharan Africa (see for example Cleland and Ferry (1995) and Gray et al.,(2001)), the estimates are not compatible with our model structure and its data definitions. Consequently, the original estimates of Gail and Brookmeyer were used to parameterise the model, and then the behavioural estimates changed incrementally to better reflect the epidemic in Botswana. It should also be noted that the UNAIDS estimates of the numbers of adults infected with HIV/AIDS are themselves modelled using 'sentinel data' from population sub-groups (Schwartzlander 1999). Figure 2 shows the available UNAIDS estimates from 1985-1999 together with the series produced by the compartmental model projected out to 2019.

Current work has focused on interventions that impact on sexual transmission of HIV, with interventions assumed to impact on the transmission rate though β (probability of transmission) and/or μ (number of sexual relationships). The sexually transmitted disease (STD) policy intervention investigated in this paper is based on the results of a randomized controlled trial in the Mwanza Region of Tanzania, which found that the treatment of sexually transmitted diseases produced a 42% risk reduction in seroconversion due to a reduced probability of transmission (Grosskurth 1995). We have mimicked this using a 50% and 30% reduction in β among high risk, and mixed risk relationships respectively. The impact of this intervention if implemented nationally in 2003 is shown in Figure 2. The per capita unit cost in the Mwanza study was US$ 0.39 per capita (Gilson 1997, with 1993 price levels). The mass media education intervention used in this study describes the higher costs associated with a national publicity campaign raising awareness of HIV/AIDS. This is modeled using a 25% reduction in μ for all risk categories and is costed at US$ 0.35per capita (Soderlund 1993, adjusted to 1993 price levels).

Figure 2 UNAIDS and modelled estimates of HIV/AIDS prevalence



4. Data and Model

Computable General Equilibrium Model

The CGE model is an early version of the IFPRI standard model (see Lofgren, *et al*., 2002, for the latest version). The most notable feature of the model is that it allows for secondary production, i.e., activities (industries) are allowed to produce more than one commodity. This feature permits the model to draw directly upon SAMs produced in accordance with the UN System of National Accounts, and hence avoids the reduced form SAMs that characterise the majority of CGE models that follow Dervis *et al*., (1982). This is particularly relevant when modelling food systems since the food systems, and in particular agriculture, are typically characterised by multi-product industries (farms). It also means that exports are from the commodity accounts rather than the activity accounts. The model is specified as a mixed complementarity problem (see Rutherford, 1995, and Lofgren and Robinson, 1997), and allows for the modelling of transport and marketing margins.

The model is in the general class of structural neoclassical models (see Chenery, 1975). The modelling of production relations and factor demands allows for substitutability between factors, i.e., capital for labour, and between different types of labour, and between aggregate primary inputs and aggregate intermediate inputs. Full employment is not assumed in the general case. The mapping of income to the institutional accounts is in fixed proportions of income after tax and savings.

The model makes extensive use of the Armington assumption, i.e., imperfect substitution (Armington, 1969). Activities choose the quantities of different commodities to produce on the basis of relative prices and the ease of substitutability expressed as a series of constant elasticity of transformation (CET) functions. The decision rule is profit maximisation. Domestic production is sold on either the domestic market or exported on the basis of relative prices and the ease of substitutability. Domestic outputs are then combined with imported commodities to produce composite commodities that are distributed to domestic final demand categories. The Armington assumptions for trade and factor markets are typical of many CGE models; however the modelling of exports from the commodity accounts is different, but necessary for multi-product industries. A consequence of the Armington assumption is that the impacts of changes in world prices on the economy depend upon the elasticities (degrees) of substitutability and the share of imports/exports in the composite commodities/domestic production. This typically reduces the sensitivity of the model to the specification of the elasticities of substitution.

The decisions about the quantities of commodities produced by domestic activities, exported, imported and allocated to different categories of final demands are based upon relative prices. Consequently, the price system is critical to the operation of the model. Moreover the price system encompasses the government's price policy instruments. Since governments have a wide range of price/tax instruments the price system is inevitably moderately complex. Product taxes have three specifications; tariff rates, export tax rates and sales tax rates. Taxes on production can be of two forms; indirect tax rates on production and taxes on value added[2]. The modelling of marketing margins increases this complexity. The marketing margins serve to introduce wedges between the prices paid by consumers of a commodity and its suppliers. Marketing margin rates are endogenously determined by the efficiency with which marketing services are produced. The other tax instruments are direct/income tax rates for households and enterprises.

2 This is not a value added tax, which is a tax on products.

Data

The model is calibrated with data for 1993/4. The choice of data from the early 1990s is deliberate; it can be reasonably assumed that the impact of the epidemic in the early 1990s was small and that the structure of the economy had not by that time been distorted by the epidemic. The base period model is calibrated using a Social Accounting Matrix (SAM) and associated data, while the baseline calibration involves the use of time series forecasts of some major macroeconomic variables. These are both discussed briefly below.

Social Accounting Matrix

The data used for this study are primarily derived from the Social Accounting Matrix (SAM) for 1993/4 (CSO, 1999).[3] The SAM for 1993/4 has 164 accounts; of which 54 are commodity accounts; 41 are activity accounts; 12 are factor accounts; 22 are institutional accounts with 8 household accounts, 8 enterprise accounts and 8 government accounts; 9 redistribution accounts; 14 are capital accounts; 5 are Rest of the World accounts; and 7 are Asset accounts. For purposes of this study the published SAM has been reorganised and aggregated to produce a real economy SAM with 106 accounts, i.e., excluding the asset accounts. The main changes were to eliminate the redistribution accounts using the method of apportionment (Pyatt, 1989), aggregate the enterprise, capital and rest of world accounts to form single accounts. The entries for the mixed income factor account were allocated between labour and capital using secondary data and an account for the factor land was added. The treatment of marketing margins was also adjusted; this required a revision to the commodity accounts. A list of the 106 accounts in the final SAM is given in the Appendix, Table A1.

Table 1 A 'Macro' SAM for Botswana 1993/4 (Pula millions)

	Commodities	Activities	Factors	Households	Enterprises	Taxes	Government	Capital	Rest of World
Commodities	1,957.4	6,418.8	0.0	3,691.4	380.4	0.0	3,243.7	2,838.1	5,421.8
Activities	16,775.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Factors	0.0	10,372.2	0.0	0.0	0.0	0.0	0.0	0.0	-0.9
Households	0.0	0.0	3,785.3	23.0	337.4	0.0	100.6	-0.9	77.9
Enterprises	0.0	0.0	6,171.7	78.0	0.0	0.0	342.7	-3.2	859.8
Taxes	940.2	-16.0	0.0	106.8	1,260.2	0.0	0.0	0.0	0.0
Government	0.0	0.0	383.7	149.6	2,196.4	2,291.2	0.0	-6.3	203.4
Capital	0.0	0.0	18.4	283.2	2,132.9	0.0	1,527.9	0.0	-1,134.0
Rest of World	4,279.0	0.0	12.2	-9.4	1,142.4	0.0	3.1	0.7	0.0
Totals	23,951.6	16,775.0	10,371.3	4,322.6	7,449.7	2,291.2	5,218.0	2,828.4	5,428.0

Source: Model database.

An indication of the structure of the economy can be gathered from a 'macro' SAM that can be derived from the 106 account SAM used to calibrate the model (Table 1). Certain

3 This is the seventh SAM that has been produced for Botswana. Since the first SAM, for 1975, the national accounts for Botswana have been heavily influenced by the underlying concepts of a SAM, and the CSO has now adopted a strategy of producing new a SAM every 3 years.

features deserve a brief mention. The economy is open with imports and exports accounting for 17.9 and 22.6 percent of commodity supply and demand respectively. Intermediate inputs account for 38.3 percent of activity inputs with primary factors accounting for 61.8 percent. Households provide 15.4 percent of domestic demand, closely followed by government (13.5 percent) and investment (11.8 percent). Marketing margins are relatively high, accounting for 8.2 percent of commodity transactions.

The government's income comes almost equally from taxes (39 percent) and royalties from enterprises (37.4 percent), and direct taxes on enterprises, but not households, make a substantial contribution to tax revenue. The rate of tariffs was high, but the revenue was not critical for the government. The government surplus, at 11.2 percent of income, was appreciable, as was the surplus on the current account. Investment was buoyant relative to activity gross output. Overall the image is of a strong economy, albeit an economy that is heavily dependent for government revenues on the diamond industry via the enterprises account.

Other data used to calibrate the CGE model are recorded as a satellite account for the Factor: Activities accounts. Statistics for employment were provided by the CSO using activity and factor classifications matched to those in the SAM. In addition the CSO provided estimates of the average numbers of hours worked each week by different types of labour. Labour services are therefore recorded as hours per year. Gross capital stock estimates are published in the SAM for those activities recording gross operating surpluses. For several industries, mostly agriculture, neither gross operating surpluses nor gross capital stocks are recorded. Rather transactions are recorded in terms of mixed income, i.e., payments to labour, capital and land. Data from the agricultural survey was used to estimate the imputed value of family labour services and imputed rental payments for land; the residuals were attributed to capital.[4]

Time Series Forecasts

The calibration of the recursive dynamic model requires estimates of macroeconomic variables that the model will target/replicate. Forecasts are provided for real GDP (RGDP), imports (MGSR), exports (XGSR), real gross domestic investment (GDIR) and population. When generating these forecasts is it necessary to assume that they are estimated from stable models which are not affected by large HIV prevalence (i.e. a non-AIDS baseline). With this in mind the forecasts (and prediction errors) have been generated for the period 1994 to 2020, from models estimated over the period 1960 to 1993.

All forecasts have been generated from univariate ARIMA models chosen on the basis of parsimony. The model performance is judged largely by their ability to model the

4 The interpretation of the 'return to land' is arguably ambiguous given that 70 percent of land is designated as 'communal land' (See Government of Botswana, 1997, p 229 and Chapter 14).

autocorrelation of the series and residuals from all models display no remaining autocorrelation as judged by the Ljung-Box statistic. Augmented Dickey Fuller tests suggest that all series, except for the population series, are I(1); therefore they are forecast from models in first differences with the remaining autocorrelation modelled as an AR(1) process. The population series is trend stationary with remaining autocorrelation modelled as an AR(2) process. The model for the real GDP series contains a dummy variable to take account of an outlying observation in 1987. All estimation was done using Eviews 4.0.

5. Analysis

Policy Experiments

The policy experiments are necessarily fairly simple and stylised, and involve some restrictive assumptions. In total there are 'six' policy experiments, although these encompass only two substantive changes that represent positive responses that are intended to ameliorate the worst effects of the epidemic. The interventions are both introduced from 2000, while the model simulation period runs from 1994 to 2020. The details of the experiments are as follows:

1. This is the baseline, or business-as-usual, scenario. The intention of this scenario is to quantify how the economy would have been expected to develop provided it continued to follow the 'path' it took from independence until the early 1990s. All the subsequent results should be interpreted relative to the results for this scenario.
2. The impact of the epidemic on Botswana if the workforce declines as a consequence of HIV/AIDS BUT other than the decline in the workforce there are no other adverse effects or costs.
3. The impact of the epidemic on Botswana if the workforce declines as a consequence of HIV/AIDS AND the government faces increased health care expenditures per infected person solely as a result of the epidemic. These expenditures related only to palliative care. Over the period (1994 to 2020) the provision of (real) health care increases by approximately four times.
4. The impact of the epidemic on Botswana if the workforce declines as a consequence of HIV/AIDS AND the government faces increased health care expenditures per infected person solely as a result of the epidemic, BUT responds by increasing the provision of treatment for Sexually Transmitted Diseases (STDs). This intervention impacts upon the *beta* parameters in the epidemiology model; it is assumed that the effects of the STD treatments are a reduction of 50 percent in the chance of transmitting HIV through sex between high risk partners and 30 percent through sex involving at least one low risk partner.

5. The impact of the epidemic on Botswana if the workforce declines as a consequence of HIV/AIDS AND the government faces increased health care expenditures per infected person solely as a result of the epidemic, BUT responds with an education programme that succeeds in reducing the numbers of new sexual partnerships. This intervention impacts upon the *mu* parameters in the epidemiology model; it is assumed that the education programme reduces the number of new sexual relationship across both risk categories by 25 percent.
6. The impact of the epidemic on Botswana if the workforce declines as a consequence of HIV/AIDS AND the government faces increased health care expenditures per infected person solely as a result of the epidemic BUT responds by increasing the provision of treatment for Sexually Transmitted Diseases (STDs) AND with an education programme that succeeds in reducing the numbers of new sexual partnerships. This captures the combined effects of changes in the *beta* and the *mu* parameters in the epidemiology model using the same changes as in scenarios 4 and 5.

It is important to consider the closure rules adopted to develop the baseline and then how results from the baseline cases were used to control the scenarios. Macroeconomic control totals, derived from the econometric forecasts, were used to impose the time path of GDP, investment and the workforce; it was assumed that availability of each type of labour grew in line with the total workforce.[5] In the baseline case the efficiency parameters on production were allowed to vary, as were the shares of total absorption accounted for by investment and the real volume of government expenditure; for the scenarios these variables were fixed. The scenarios therefore represent an optimistic view about the development of the economy; in particular physical capital accumulation is protected by both the maintenance of government savings and by making the savings rates for domestic institutions variable so as to maintain the level of investment.

<u>Results</u>

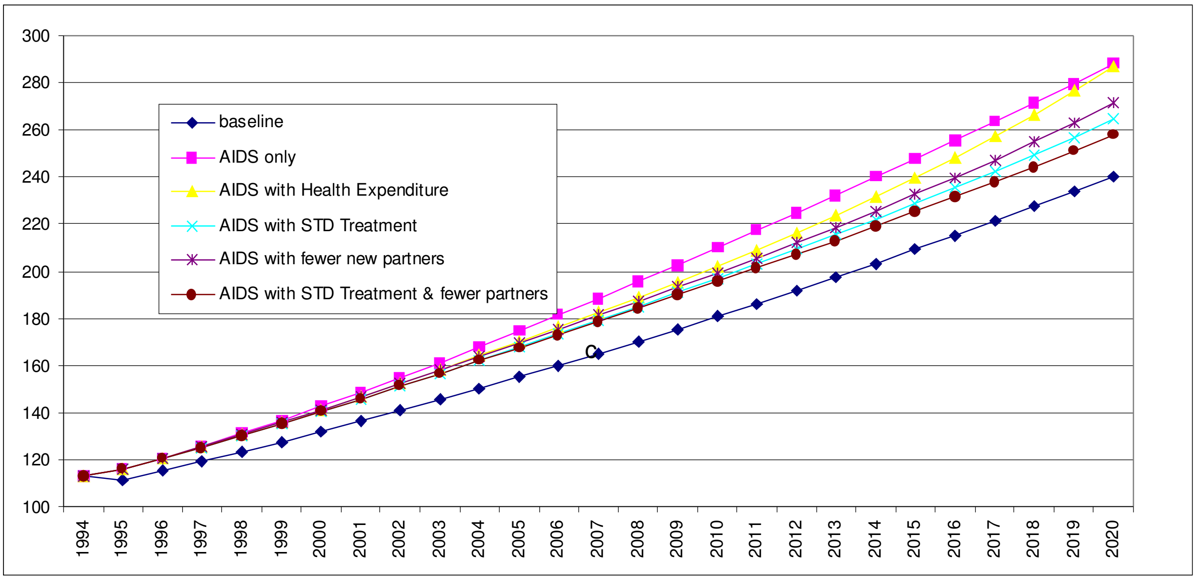
The discussion of the results focuses primarily upon macroeconomic indicators relative to the baseline. In all cases the graphics report the results adjusted for changes in population; these are not presented as absolute/per capita values but relative to the population in the base period.[6] The impact of the policy scenarios upon GDP 'per capita', see Figure 3, are initially somewhat surprising: in all cases the time path of GDP is above the baseline, which suggests that the epidemic would benefit the economy, a conclusion that seems to be reinforced by the

5 Although the model contains a physical capital accumulation function it does not allow for any (endogenous) human capital accumulation.

6 This is because on a shortage of data on the absolute numbers of households/individuals in each representative household group.

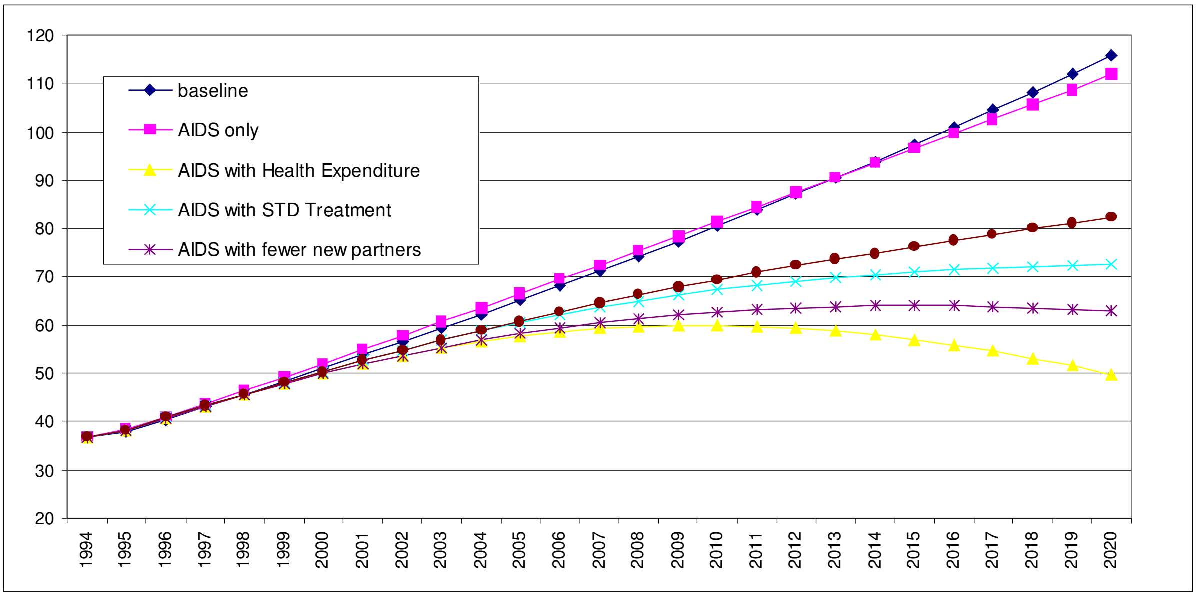
results that suggest that interventions only serve to reduce GDP 'per capita'. In one respect these results are unsurprising; the scenarios are all run with a selection of closure rules that preserves the value of investment and hence the capital labour ratio (see Figure 11 below) rises most where the labour force expansion is least, when there is no intervention – the 'AIDS only' scenario – and least when the impact of the epidemic on the labour force is least when there is no epidemic – the baseline.

Figure 3 GDP 'per capita'



Source: Simulation results.

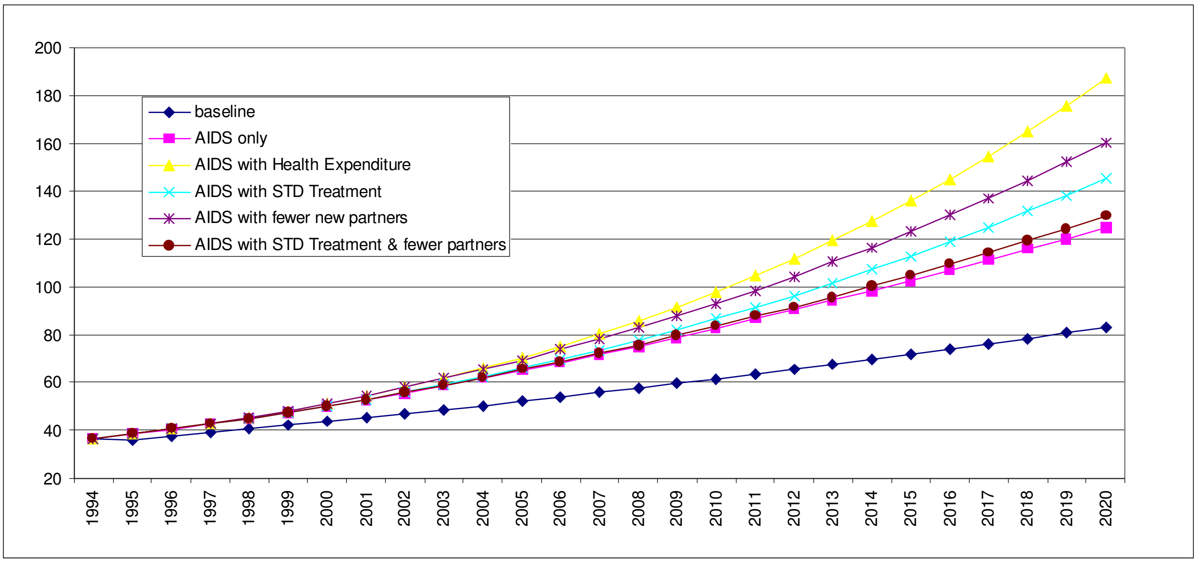
Figure 4 Private Consumption 'per capita'



Source: Simulation results.

It is therefore instructive to consider the impact of the epidemic scenarios upon the components of GDP rather than GDP. Several features of the impacts of the various scenarios upon consumption per capita stand out (see Figure 4). First, if there is no response to the epidemic - the AIDS with Health Expenditure scenario - then consumption per capita continues to rise until 2010 but thereafter declines so that by 2020 it has fallen below the level in 2000. Second, interventions in the form of STD treatment and education that reduces the numbers of new sexual partners have substantial positive benefits; in 2020 consumption per capita is some 32 percent greater from the reduction in new sexual partners, 56 percent greater from STD treatment and 85 percent greater with both. Third, the reduction in the number of new sexual partners alone is not enough to avoid a reduction in consumption per capita in 2020 from the peak level. And fourth, if AIDS has no effects other than reducing population - the AIDS only scenario - then consumption initially rises slightly above the baseline but then, as input substitution becomes less rewarding, the growth path falls below the baseline.

Figure 5 Government Consumption 'per capita'

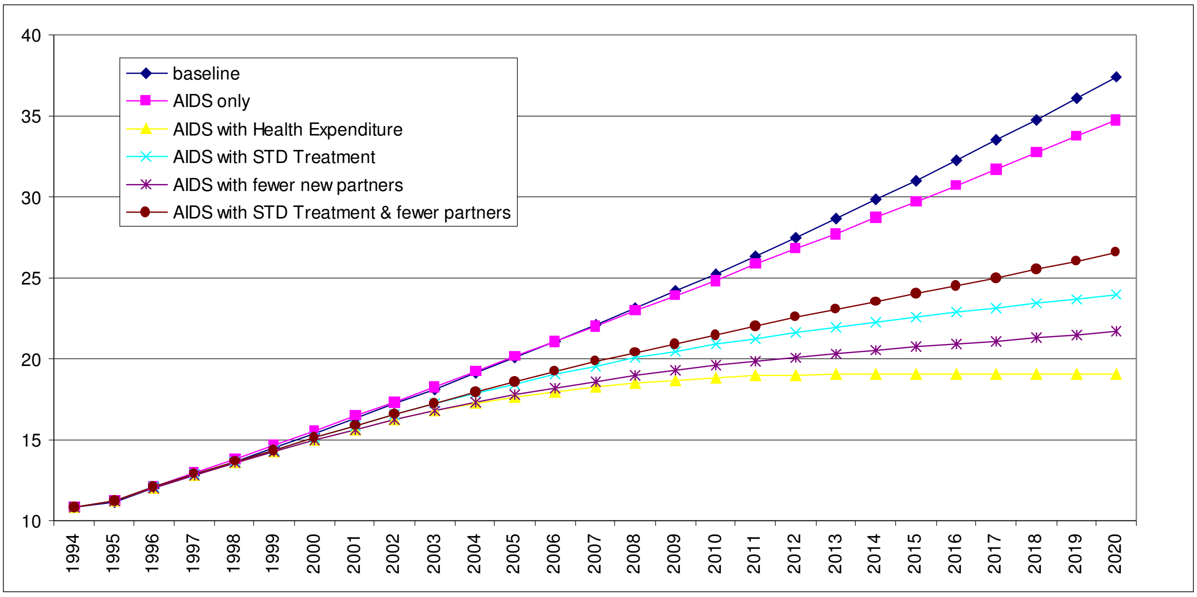


Source: Simulation results.

The combination of the slow growth of consumption per capita and the fixed share of absorption going to investment (see Appendix Figure A1) inevitably sees the growth in GDP per capita being largely accounted for by increases in Government Consumption, Figure 5. Without the epidemic Government consumption was due to expand in line with domestic absorption – the baseline case. Without interventions that reduce the extent of the epidemic – the AIDS only scenario – government consumption rises rapidly and at an increasing rate. But even though the interventions sharply reduce the increases in government consumption, by nearly 60 percent in the scenarios where both interventions take place; this is not enough to reduce the substantial upward trend in government consumption.

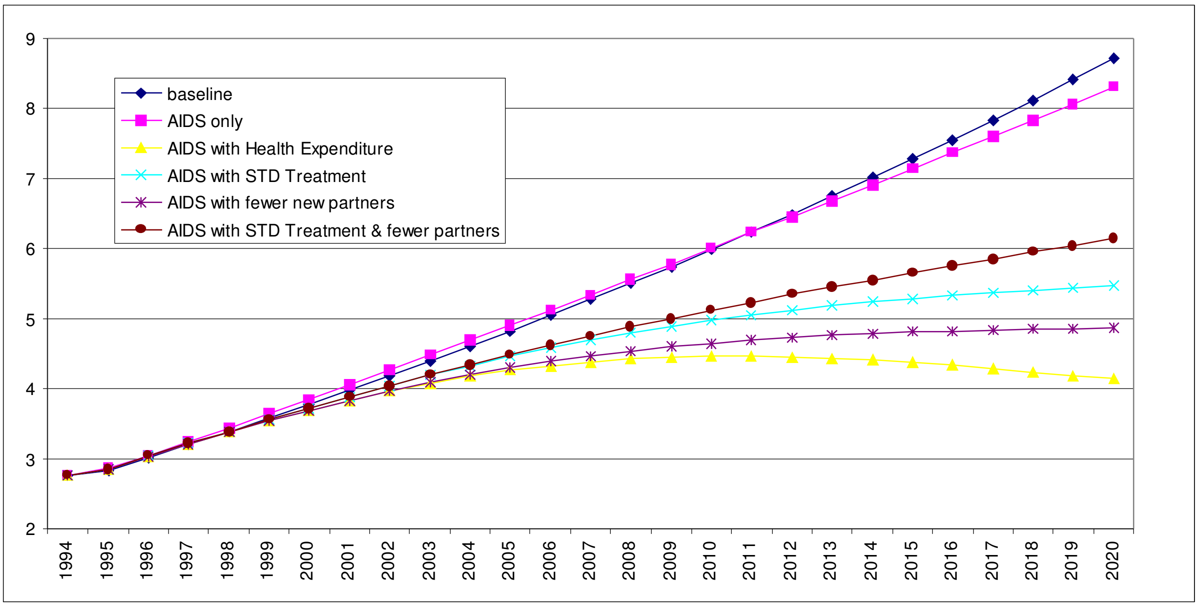
The impacts of the epidemic on disposable income per capita by each household group follow the same basic pattern (see Figures 6 to 10). The epidemic combined with increased health care expenditures severely reduces disposable income per capita, but this is ameliorated by the interventions. In most cases the loss of disposable income per capita is halved with both interventions.

Figure 6 Disposable Income 'per capita' for Urban Waged Households



Source: Simulation results.

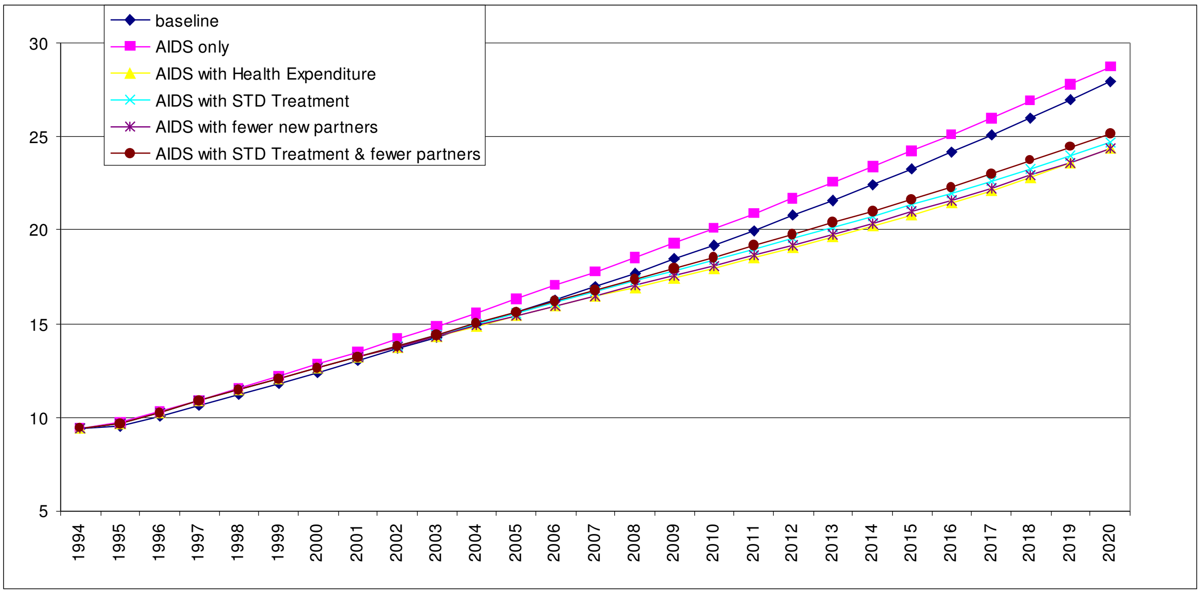
Figure 7 Disposable Income 'per capita' for Urban Self Employed Households



Source: Simulation results.

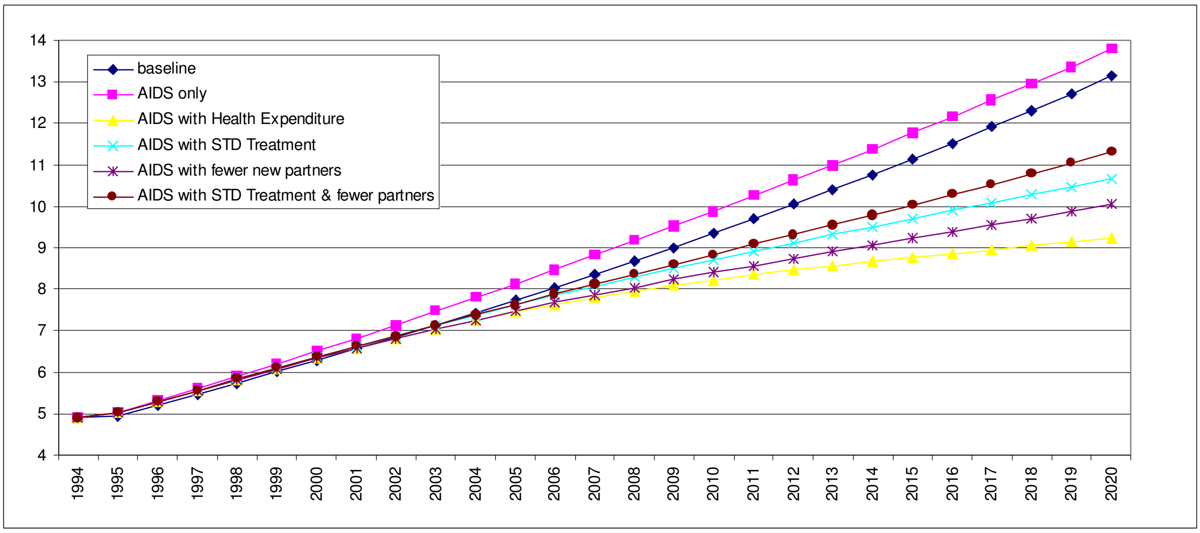
However although the general picture holds there are substantial variations across the different household groups. Urban Waged households (Figure 6) suffer a smaller proportionate decrease, relative to the baseline, than the Urban Self Employed (Figure 7), although in both cases the outcome with both interventions is still a reduction in disposable household income of nearly 30 percent. In both cases however this is appreciably less severe than the approximately 50 percent reductions when no interventions are implemented.

Figure 8 Disposable Income 'per capita' for Rural Waged Households



Source: Simulation results.

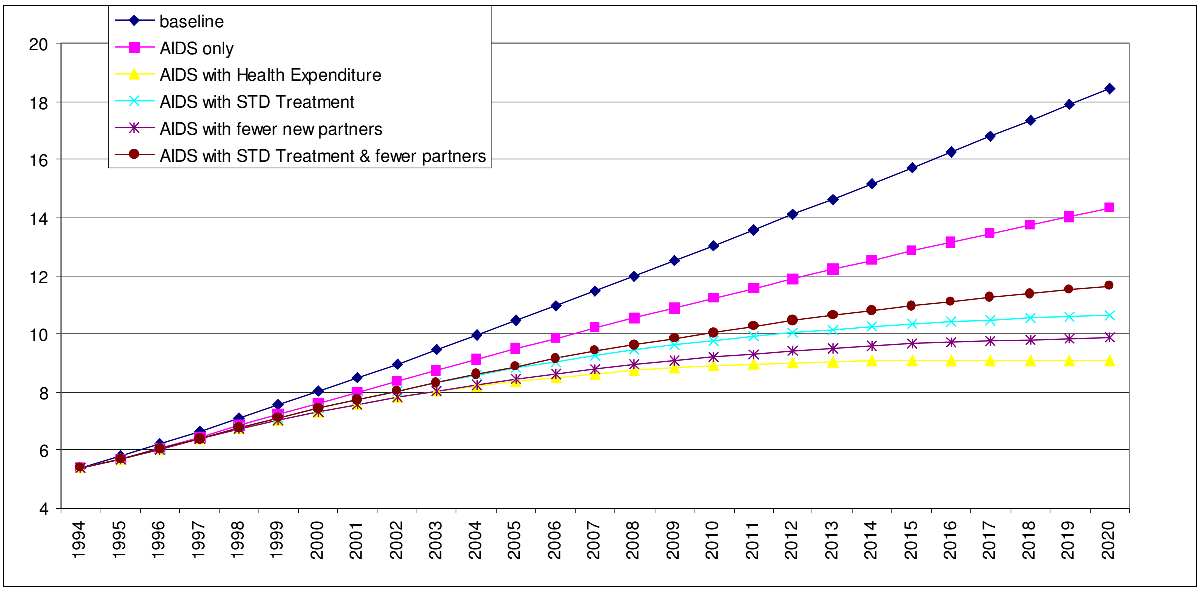
Figure 9 Disposable Income 'per capita' for Rural Self Employed Households



Source: Simulation results.

On the other hand the impact upon rural households is much smaller, especially for Rural Waged households, who at worst only experience a 13 percent reduction in disposable income per capita, and with both interventions only lose 10 percent of disposable income. Rural Self Employed households do less well; at the worst disposable income drops by 30 percent and even with both interventions this loss of income is only reduced to 14 percent.

Figure 10 Disposable Income 'per capita' for Non-Citizen Households



Source: Simulation results.

However the most severely affected households are the non-citizens. Even with both interventions they experience a loss of some 37 percent of disposable income, while with no interventions but increased heath care expenditures their disposable incomes decline by over 50 percent. The relative effects across the different household groups are summarised in Table 2. However it is important to recognise that these effects are only so large because the baseline for non-citizen households was so high, i.e., without AIDS it was assessed that non-citizen households were expected to benefit as much as any citizen household group and more than all but one group.

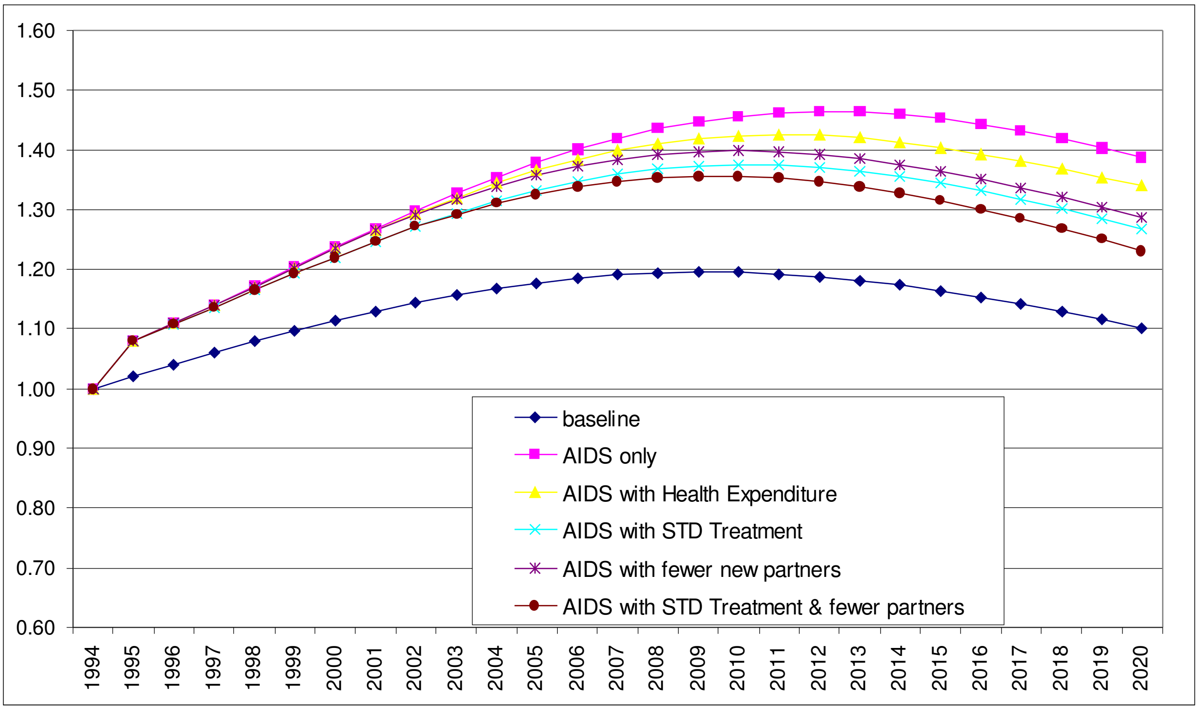
Table 2 Relative Changes in Household Disposable Incomes 'per capita'

	Urban Waged	Urban Self Employed	Rural Waged	Rural Self Employed	Non-Citizen
baseline	100%	100%	100%	100%	100%
AIDS only	93%	95%	103%	105%	78%
AIDS with Health Expenditure	51%	47%	87%	70%	49%
AIDS with STD Treatment	64%	63%	88%	81%	58%
AIDS with fewer new partners	58%	56%	87%	76%	54%
AIDS with STD Treatment & fewer partners	71%	71%	90%	86%	63%

Source: Simulation results.

Clearly there are substantial changes taking place in the factor markets, both in terms of changes in the capital labour ratios and in terms of factor prices. The capital labour ratios, Figure 11, indicate the importance of the assumption that investment volumes are maintained; the impact of epidemic is to increase capital labour ratios inversely to the extent of the mortality rates. One 'downside' therefore of interventions is that the capital labour ratios decline, which implies that the increase in wage rates will, *ceteris paribus*, be less. This is confirmed by the changes in factor prices – all expressed relative to the factor's price in the base period. However the picture that emerges is far from straightforward, in some cases, e.g., Professional citizens, the impact of the epidemic and interventions results in greater increases in wage rates where for other factors , e.g., Clerical citizens, farm workers and land, the epidemic and interventions result in lower relative wages rates.

Figure 11 Capital Labour Ratios



Source: Simulation results.

Table 3 Relative Changes in Household Disposable Incomes 'per capita'

	Professional		Administrator		Clerical		Skilled		Unskilled	Farm Worker	Capital	Land
	Citizen	Non-citizen	Citizen	Non-citizen	Citizen	Non-citizen	Citizen	Non-citizen				
baseline	1.94	2.78	2.11	2.97	3.19	3.01	2.11	2.69	2.16	2.30	1.96	3.21
AIDS only	2.37	2.67	2.28	2.57	3.44	2.62	2.22	2.27	2.28	2.31	1.95	2.69
AIDS with Health Expenditure	3.51	3.34	2.64	2.56	3.04	2.28	2.47	2.21	2.44	1.60	2.54	1.67
AIDS with STD Treatment	2.86	2.93	2.30	2.47	2.56	2.34	2.17	2.11	2.30	1.91	2.22	2.19
AIDS with fewer new partners	3.10	3.08	2.41	2.48	2.73	2.30	2.26	2.13	2.34	1.78	2.34	1.97
AIDS with STD Treatment & fewer partners	2.63	2.81	2.21	2.49	2.40	2.42	2.10	2.15	2.27	2.04	2.13	2.42

Source: Simulation results.

The changes in factor prices are substantial, see Table 3. The baseline scenario indicates that factor prices increase by between 1.94 and 3.21 times over the period 1994 to 2020, and typically the non-citizen workers experience somewhat higher increases than citizens – the exception is clerical workers.[7] As would be expected the price of labour rises relative to capital and land in the AIDS only scenario, with capital experiencing an insignificant reduction in price and land experiencing a substantial reduction in price. But in the health care expenditures and intervention scenarios producing more difficult to interpret results; despite the reductions in mortality with the interventions the wages for citizen workers generally increase and there is no clear pattern. It seems that this is a reflection of the structural changes the economy is required to undergo to achieve equilibria in each success cycle of the model, but it needs further investigation.

6. Concluding Comments

Overall therefore the impact of the epidemic is a serious reduction in the potential consumption, about 70 percent of private consumption is lost, or alternatively consumption only increases by 40 percent rather than 70 percent. Similarly the disposable incomes of households in Botswana fall substantially compared to the baseline, between 53 and 13 percent. These are non trivial reductions in the levels of welfare that might have been realised without the epidemic, and alone are sufficient to justify advocacy for interventions. In this case the two interventions analysed offer the prospect of substantial benefits; typically the interventions examined can offset 50 percent or more of the projected welfare losses. However there remains much to be done.

Three further developments to the epidemiological model described here are being developed in order to provide estimates of greater relevance to policy makers. These are

i) the inclusion of morbidity and productivity associated with HIV infection;

ii) disaggregation of the epidemiological model down to types of household; and

iii) the inclusion of active (as opposed to palliative) AIDS treatment.

The inclusion of morbidity is an important consideration as evidence shows that illness, particularly in the later stages of the disease can have a dramatic effect on productivity; at present, only mortality effects are included within the model. Morris (2000), for example, found that productivity losses and absences produced reductions in working time equivalent to 56 days per worker in the final two years of employment. The simplest way to incorporate morbidity is to apply a negative productivity effect for all infecteds. This, however, may be over-simplistic as early stage HIV infections have little impact on productivity. A more

7 In part this is a consequence of the assumption that the numbers of non-citizen workers are fixed.

sophisticated approach is to split the infecteds into separate HIV and AIDS categories. This would allow the productivity adjustment to fit better with the evidence, and allow refinement of the palliative treatment costs, which could be applied to AIDS patients only. An even more complex way would be to develop a model of HIV progression based on CD4+ counts which maps out productivity costs for each year following infection (Lui 2002). This, however, would require a very complex modelling exercise that would be limited by data availability.

Disaggregation of the epidemiological model down to types of household would allow differences in prevalence, sexual behaviour and intervention effectiveness to vary by population group. Incorporation of this would produce differential effects from interventions and allow policy makers to target their policies to the most appropriate population groups. This would require separate μ's, β's and ρ's for each household type, which would place a high premium on data availability. However, illustrating the importance of this model development would highlight some of the benefits from collected these data.

Finally, it would be possible to add a third compartment by splitting the infecteds into those receiving, and not receiving, antiretroviral therapy (ART). Up until the last couple of years, the provision of these expensive medications in less developed countries was unthinkable. However, a growth in the production of cheap generic medications means that it is now a viable policy option. ART slows down the progression of disease dramatically, thus delaying the onset of AIDS, reducing productivity losses associated with morbidity, and lowering the mortality rate. Another effect is that the lower CD4+ counts that ART produces also reduce the probability of transmission, although with a higher prevalence of infecteds due to reduced mortality, the precise effect of ART is complex. Furthermore, work by Nagelkerke (2001) points to a STD intervention such as that used in this paper being more effective than ART, as poorly implemented therapy can encourage drug resistant strains that limit the policy's effectiveness. The incorporation of ART into the epidemiological model, and evaluation of these policy options will be investigated once better information is known about the availability of generic ART in Botswana.

There is also a need to further develop the CGE model. Some of the CGE model developments are needed to 'mirror' developments in the epidemiological model; in particular there is a perceived need to provide a closer tracking of asset ownership, particularly, by households so as to provide a better understanding of how the functional distribution of income might change. Similarly there are arguments for improvements to the capital accumulation functions with respect to both physical and human capital; the current results are perceived to be overly dependent upon the assumptions about investment. Finally, the very large price changes associated with the epidemic have so far limited the extent to which it has be possible to model morbidity without generating 'extreme' results.

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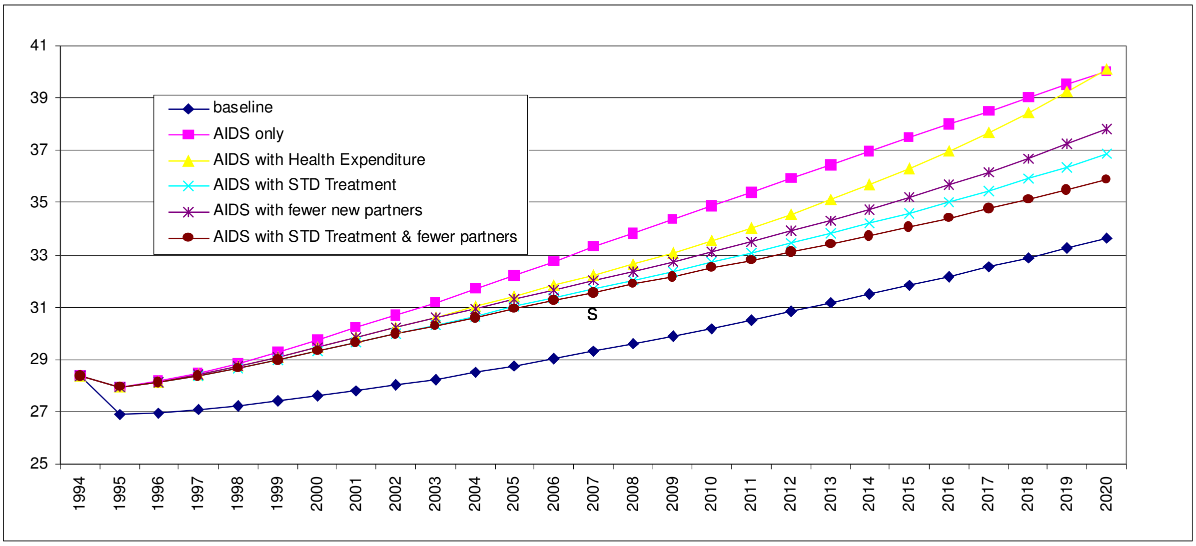
Appendices

Table A1 Model Accounts

Commodity Accounts	Activity Accounts	Factor Accounts
Cattle	Trad Agric Cattle	Prof & Tech Employees Citizen
Other Livestock	Trad Agric Other	Prof & Tech Employees NonCitizen
Fruit veg & Nuts	Freehold Farms	Admin & Manag Employees Citizen
Cereals	Hunting Fishing & Gathering	Admin & Manag Employees Non Citizen
Other Agricultural Produce	Mining Diamonds	Clerical Employees Citizens
Mining	Copper Nickel	Clerical Employees NonCitizens
Sand Gravel Cement	Coal	Skilled Manual Citizens
Meat & Products	Soda Ash	Skilled Manual NonCitizens
Dairy Products, Oils & Fats	Other Mine	Unskilled Employees
Other Food	Meat Processing	Farm Employees
Beer & Soft Drinks	Dairy & Other Agric Processing	Gross Operating Surplus
Other Beverages & Tobacco	Beverages	Land
Textiles & Clothes	Textiles	
Hides & Skins	Chemicals	**Household Accounts**
Chemicals, Plastics & Petroleum	Transport & equipment	Urban Households Wage Income
Paper & Products	Metal Products	Urban Households Selfemployed
Bricks Glass & ceramics	Manufacturing	Urban Households Transfers
Metals & Metal Goods	Water	Rural Households Wage Income
Other manufacturing	Electricity	Rural Households Selfemployed
Water	Construction	Rural Households Transfers
Electricity	Trade	NonCitizen Households
Construction	Hotels & Restaurants	
Wholesale & Retail Margins (by 4)	Rail Transport	**Tax Accounts**
Hotels & Retaurants	Road Transport	Direct Taxes
Rail Transport	Air Transport	Sales Taxes
Road Transport	Other Transport	Tariffs
Air Transport	Communications	Export Taxes
Communications	Banking & Insurance	Value Added Taxes
Finance & Insurance	Business Services	Indirect Taxes
Business Services	Ownership of Dwellings	Factor Taxes
Rent	Central Government	
Ownership of Dwellings	Domestics Services & Trad'l Doctors	**Other Accounts**
Central Government	Other Personal Services	Enterprises
Education	PNPISH	Government
Health Private		Capital Account
Health Subsidised		Rest of the World
Domestic Services		
Personal Services		

Figure A1 Investment 'per capita'



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Source: Simulation results.