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Modelling the Impact of HIV/AIDS: A Literature Review

by

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Modelling the impact of HIV/AIDS:
A literature review

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Abstract

A number of methods and models have been used to analyse the economic impacts of HIV/AIDS. The overall consensus is that depending on the severity of the epidemic, HIV/AIDS holds serious negative consequences for economic growth and economic welfare. The aim of this paper is to give a broad overview of the methodologies used in analysing the economic impact of HIV/AIDS on various countries, including South Africa. The literature review is structured by method of analysis. For each method, selected papers are briefly described.

This paper is set out as follows: Section 1 describes studies using econometric estimation. This method is useful in cross-country analysis and allows for the impact of the disease to be compared internationally. Section.2 describes studies applying country-specific macroeconometric models to examine the impact of HIV/AIDS. Section 3 describes the use of aggregate growth models. These models extend the Solow model, allowing HIV/AIDS to be captured via the reduction in employment and population growth. These country-specific models are useful in analysing the impact of HIV/AIDS on economic growth and per capita income. Section 4 describes the use of country-specific CGE models in the analysis of HIV/AIDS. Section 5 reviews other methods used for analysing the impact of HIV/AIDS on an economy. These methods include overlapping-generations models, demographic models and sector-specific analysis. The paper ends with concluding remarks.

Keywords: HIV/AIDS, Africa,

JEL classifications: I190, O55

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AIDS	Acquired immunodeficiency syndrome
ART	Antiretroviral therapy
ASSA	Actuarial Society of South Africa
BER	Bureau for Economic Research
BIDPA	Botswana Institute for Development Policy Analysis
HIV	Human immunodeficiency virus
IMF	International Monetary Fund
TFP	Total Factor Productivity
UN	United Nations
WHO	World Health Organisation

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1. ECONOMETRIC ANALYSIS

Econometric analysis has been used to analyse the impact of HIV/AIDS across a number of countries. An advantage of this method is that, given the severity of the epidemic, the impact of HIV/AIDS can be compared across countries. One of the first attempts to model the impact of HIV was conducted by Over (1992). He estimates the macroeconomic impact of AIDS on 30 Sub-Saharan economies by projecting growth "with AIDS" and "without AIDS" over the period 1990–2025. He models the impact of HIV/AIDS by capturing the link between economic growth, capital accumulation and the demographic impact of AIDS. Based on the values of key parameters he finds that even if AIDS is spread uniformly across the skill classes of workers, the AIDS epidemic can reduce the growth in per capita GDP if at least 50 per cent of the treatment cost is funded via domestic savings. The result is worsened if the epidemic is biased toward more educated classes (Over, 1992: 24). He finds that the timing of the epidemic is important and that countries that are more advanced along the epidemic path experience a more severe impact (Over, 1992: 23). The net effect of the AIDS epidemic on the growth of per capita GDP is a reduction of about a 0.3 per cent in the 10 countries that are most affected (Over, 1992: 25).

Bloom and Mahal (1997) conduct a cross-country analysis that examines the statistical link between changes in HIV prevalence and the rate of growth of GDP per capita across 51 developing and industrial countries. The period of the study is from 1980 to 1992. They estimate a growth function with the rate of growth in real GDP per capita as the dependent variable. Their model equations are:

$$GDP_i = \beta_0 + \beta_1 AIDS_i + X_{i\pi} + \varepsilon_i \qquad \text{(E.1)}$$

$$AIDS_i = E\left(\alpha_k, HIV_{it}, FHIV_i, PHIV_i\right) \qquad \text{(E.2)}$$

$$HIV_i = \delta_0 + Z_1\left(GDP_i\right)\delta_1 + Z_2\delta_2 + \mu_i \qquad \text{(E.3)}$$

where i refers to countries, GDP is the rate of growth in real per capita GDP, $AIDS_i$ is the annual increase in the cumulative AIDS prevalence, X represents variables that impact on economic growth, Z_1 and Z_2 represent variables that influence HIV transmission, HIV_t is an estimate of the number of HIV cases in year t, $FHIV$ measures the maturity of the epidemic (number of years between when HIV first entered the country and year t), $PHIV$ measures the number of years between when HIV entered the country and when the peak number of new HIV cases is projected to occur, E is the EPIMODEL map from HIV_t, $FHIV$, $PHIV$ to

AIDS, α_k is a parameter in the EPIMODEL, which is non-uniform over countries, β_0, β_1 and π are parameters to be estimated and ε and μ are errors each with zero mean (Bloom & Mahal, 1997: 112–113). Substituting (E.2) and (E.3) into (E.1) yields:

$$GDP_i = \beta_0 + \beta_1 E^*\left(\alpha_k, HIV_{it}, FHIV_i, PHIV_i\right) + X_i \pi + \varepsilon_i \qquad \text{(E.4)}$$

The aim of their analysis is to obtain consistent estimates for β_1. Bloom and Mahal use a non-linear two-stage least squares procedure to estimate the relevant parameters. Their results find no evidence that countries with higher AIDS prevalence grow at a slower pace than countries with lower AIDS prevalence. When they introduce the control variables (initial level of GDP per capita, government expenditures on education, average schooling, population growth and birth rate) they find that the negative link between the change in HIV prevalence and economic growth is established because HIV prevalence is higher in countries with characteristics associated with slower GDP growth and not because AIDS has an independent negative impact on economic growth (Bloom & Mahal, 1997: 118). The paper concludes that the AIDS epidemic may have a significant impact on development even though the impact on per capita GDP is insignificant.

Bonnel (2000) develops an econometric model consisting of three equations to model the relationship between average economic growth and HIV prevalence across 70 to 80 countries. The simulation period is from 1990 to 1997. They estimate the growth equation with two-stage least squares to determine the relationship between economic growth and HIV prevalence. The percentage change in GDP is the dependent variable and the independent variables include secondary school enrolment, legal framework, share of females in the labour force, the number of Muslims in the population and the number of years since the first HIV cases were reported. Unlike the previous study, Bonnel finds a significant negative relationship between HIV prevalence and economic growth. Results suggest that the impact on economic growth is very small for countries with low HIV prevalence rates. For African countries with an average prevalence rate of 8 per cent the rate of economic growth is reduced by approximately 0.7 per cent. Countries with high prevalence rates experience a larger reduction in per capita GDP. A typical sub-Saharan country with a prevalence rate of 20 per cent experienced an annual decline of 2.6 per cent in the rate of GDP growth. Over a 20-year period GDP per capita would be 67 per cent lower (Bonnel, 2000: 368–369).

Alemu *et al.* (2005) construct a panel of data for over 100 countries for the years 1994 to 2002. Their study focuses on the impact of HIV/AIDS on total factor productivity (TFP) growth in each country. They find that HIV/AIDS poses no threat to most of the countries included in their study. This is because more than 75 countries in their study have a prevalence rate of less than 1 per cent (Alemu *et al.*, 2005: 12). For countries with higher HIV prevalence rates such as Lesotho and South Africa, the impact on TFP is more severe. They find that factor productivity growth in Lesotho falls by up to 23 per cent and for South Africa 15 per cent (Alemu *et al.*, 2005: 12).

2. MACROECONOMIC MODELS

Existing country-specific macroeconometric models can be modified to simulate the impact of HIV/AIDS. These models usually work on an aggregate economic level with very little distinction between economic sectors. For South Africa two such studies have been completed (ING Barings and BER studies). The ING Barings study uses an econometrically estimated demand-side macro model to simulate the impact of HIV/AIDS. The simulation results suggest that GDP growth would be on average 0.3 per cent lower between 2001 and 2015 in the AIDS scenario than in the “no-AIDS” scenario. The Bureau for Economic Research (BER) study finds that the overall impact of HIV/AIDS on real GDP is negative. Compared to the “no-AIDS” scenario, the level of real GDP is projected to be 1.5 per cent lower by 2010 and 5.7 per cent lower by 2015 (Laubscher *et al.*, 2001: 4).

In a more recent study completed by the BER (2006) the focus is on various intervention scenarios. The analysis compares simulation results of three scenarios: the “No-AIDS” scenario, AIDS with prevention programs but no anti-retroviral treatment (ART) program and AIDS with prevention programs including ART (BER, 2006: 1). The authors use the macroeconometric model developed by the BER to simulate the three scenarios mentioned above. The underlying assumptions incorporated in the simulations includes lower population and labour force growth, direct and indirect costs to firms, the impact of HIV/AIDS on the demand for health care and health spending by the government (BER, 2006: 2). The results for key economic variables are presented as a comparison between the three scenarios for the period 2000–2020. Their results suggest that in the absence of ART, GDP growth could fall from an average of 4.4 per cent over the simulation period to 4 per cent. They find that the economy would be 8.8 per cent smaller by 2020 than it would have been in the absence of HIV/AIDS. They also find that the population size would fall. The fall in the population size is greater than the fall in real GDP, causing per capita GDP to be approximately 8 per cent higher by 2020 (BER, 2006: 114). In terms of sector-specific analysis, they find that general government, water and electricity, mining, metals and machinery sectors are relatively seriously exposed. This is due to supply-side risk such as the high HIV prevalence rates in these sectors and demand-side risk, which includes lower final demand and exports (BER, 2006: 115). Sectors with lower overall risk include the community, social and person services, agriculture and construction industries (BER, 2006: 115).

Zerfu (2002) uses a small macroeconometric model for Ethiopia to simulate the impact of a 10 per cent decline in the labour force on the Ethiopian economy. The results suggest that agricultural and non-agricultural output decline by 2 per cent and 1.8 per cent respectively. The reduction in output leads to a fall in private consumption, investment, exports and tax revenues by 1.9 per cent, 2.4 per cent, 3 per cent and 8 per cent respectively (Zerfu, 2002).

Abdulsalam (2010) develops a macroeconometric model of the Nigerian economy to analyse the impact of a reduction in labour force participation on key macro indicators. The simulation period is from 1980 to 2000. The results are in line with the above-mentioned studies. HIV/AIDS reduces output in agriculture (0.07 per cent) and in manufacturing sectors (0.23 per cent). The reduction in output leads to a reduction of 0.11 per cent in government spending and 1.19 per cent in investment. (Abdulsalam, 2010: 15).

3. NEOCLASSICAL GROWTH MODELS AND VARIOUS EXTENSIONS

Cuddington (1993a, 1993b), Cuddington and Hancock (1994) and Cuddington *et al.* (1994) extend the standard Solow model to include variables that account for AIDS. This growth model is used to analyse the impact of AIDS on economic growth for Tanzania. In the extended model aggregate output is based on a Cobb-Douglas production function and is written as:

$$Y_t = \alpha\gamma^t E_t^{\beta} K_t^{1-\beta} \tag{E.5}$$

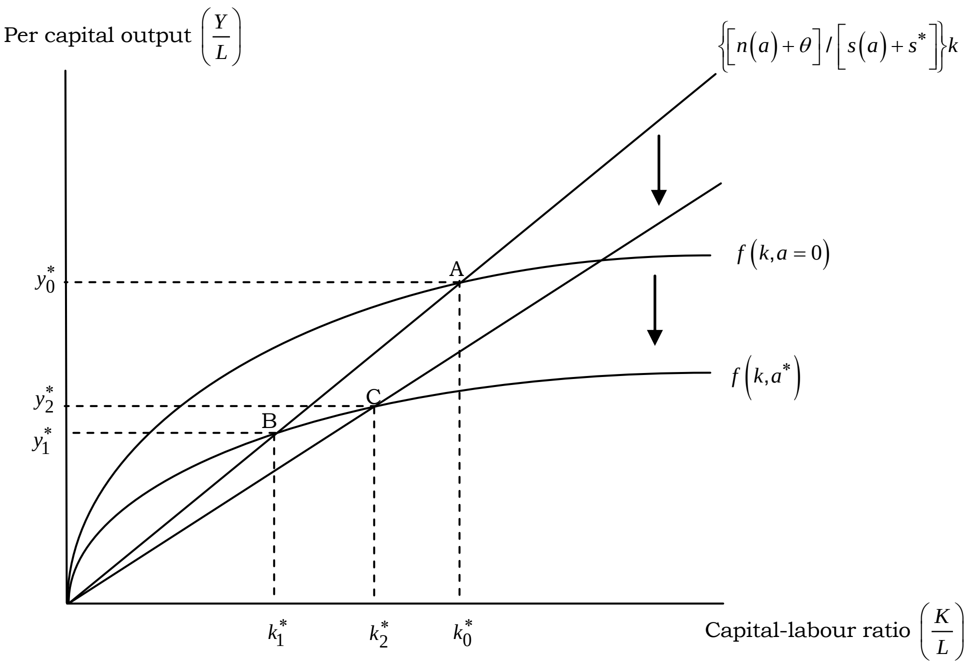
where E_t represents the labour input, K_t is the capital stock, β represents the share of labour in payment to primary factors and γ is α technological variable. The AIDS epidemic is measured as a proportion of the population that is infected. The impact of HIV on GDP arises due to the negative impact on health, experience level and the size of the labour force. Labour input is therefore defined as:

$$E_t = \left(1 - za_{it}\right)\rho_i L_{it} \tag{E.6}$$

where a_t is the proportion of the population that is infected, L_{it} is the number of workers of age i at time t, ρ captures experience of non-infected workers and z indicates the fraction of the work year lost per infected person (Cuddington, 1993a: 179). By using the extended

Solow model, the impact of an exogenous increase in AIDS prevalence can be illustrated. This is shown in Figure 1.

Figure 1. The effect of AIDS on per capita output and the capital-labour ratio



Source: Adapted from Cuddington, 1993a, Figure 1 p. 181.

Following Cuddington (1993a), the following effects are noted:

- An exogenous increase in AIDS prevalence reduces labour productivity moving the production function downwards. This moves the steady-state from point A to B. As the epidemic persists the share of younger, less experienced workers compounds this negative shift. The new steady state shows a decline in output per worker and the capital-labour ratio.
- AIDS also impacts on the population growth (labour force) n. The population growth rate falls due to an increase in AIDS, which moves the $\left\{\left[n(a)+\theta\right]/\left[s(a)+s^*\right]\right\}k$ line downwards leading to an increase in the capital-labour ratios.
- At the same time savings is a decreasing function of AIDS prevalence. With an increase in AIDS prevalence the savings rate s falls leading to lower capital accumulation. The $\left\{\left[n(a)+\theta\right]/\left[s(a)+s^*\right]\right\}k$ line moves upwards leading to lower capital-labour ratios. The final shift and the new steady state (point C) depend on which effect is more dominant (Cuddington, 1993a: 181–182).

Cuddington (1993a) applies the extended growth model to Tanzania for the period 1985–2010. The outputs of an epidemiological model for Tanzania are used in the macroeconomic projections of a "no-AIDS" and "AIDS" case. Depending on the choice of key parameters, the results show that the size of the Tanzanian economy in 2010 is between 15 and 25 per cent smaller. Per capita GDP is forecast to grow at an annual rate of 0.7 per cent in the no-AIDS scenario, compared with 0.2 to 0.7 per cent in the different AIDS cases (Cuddington, 1993a: 186).

Cuddington and Hancock (1994) apply the same extended Solow model to simulate the impact of AIDS on the Malawian economy between 1985 and 2010. In this study they simulate two different AIDS prevalence scenarios, a "medium" and "extreme" scenario. The results suggest that the average growth rate in real GDP is between 0.2 and 0.3 percentage points lower in the "medium" case and between 1.2 to 1.5 percentage points lower in the "extreme" case. Under the "medium" scenario, GDP per capita falls by 0.1 per cent and for the "extreme" scenario, GDP per capita falls by 0.3 per cent (Cuddington & Hancock, 1994: 366).

Cuddington (1993b) further extends the Tanzanian model by incorporating under-employment and dual labour markets. Within this framework, real wages are sticky in the formal sector with labour markets not clearing. The dual market economy framework allows labourers who are not hired in the formal sector to be employed in the informal, less productive sector. The simulation results show that GDP is between 15 to 25 per cent smaller by 2010 than it would have been in the "no-AIDS" baseline scenario. This leads to a fall of nearly 10 per cent in GDP per capita compared to the baseline scenario. The results further suggest that AIDS reduces labour productivity leading to a reduction in formal sector employment. Given that wages are sticky, real wages do not adjust with labour productivity and formal sector output falls. This forces more workers back into lower-income employment in the informal sector (Cuddington 1993b: 413).

Cuddington and Hancock (1995) apply the same dualistic labour market framework to analyse the macroeconomic impact of AIDS in Malawi. The idea is that per capita income may increase as formal employment vacancies are filled by workers previously employed in low-productivity activities. However, the negative impact of AIDS on the number of jobs available in the formal sector reduces the number of vacancies. Employment in the formal sector falls because of a reduction in capital accumulation and a decline in productivity. The results further suggest that by 2010 total output is 4.8 per cent lower compared to the "no-AIDS" scenario. Per capita income virtually remains unchanged as the population is also 4 per cent smaller (Cuddington & Hancock, 1995: 18). The paper concludes with a comparison of results between Tanzania and Malawi. The authors note that the impact of HIV/AIDS on the Malawian economy is not as severe as in Tanzania. There are two reasons for this: firstly, per capita income is higher in Malawi, so the economy can better absorb the increase in medical expenditure. Therefore, the negative impact of the savings rate and capital accumulation is smaller. Secondly, in both the Malawian and Tanzanian simulations, most of the economic growth is due to growth in the formal sector. However, in Malawi a higher proportion of people work in the informal sector. The implication is that less of the medical expenditures are being paid for by the reduction in capital investment in the formal sector (Cuddington & Hancock, 1995: 19).

In a World Bank series, the extended Solow model developed by Cuddington (1993b) and Cuddington and Hancock (1995) is applied to a number of Southern African countries experiencing high levels of HIV prevalence. A study for Botswana finds that between 2000 and 2015, the average real GDP growth may fall from 4.7 per cent in the "no-AIDS" scenario to 2.2 per cent in the "AIDS" scenario. The projected loss in per capita GDP is approximately 17 per cent by 2015 (World Bank, 2001a). The study for Swaziland finds that the average real GDP growth rate may fall from 3.2 per cent to 2.2 per cent for the period 1986–2015. This implies that the economy will be 34 per cent smaller by 2015. GDP per capita is projected to fall about 1 per cent per year because of a decline in population growth (World Bank, 2001c). The study for Namibia finds that GDP is projected to grow at 2 per cent by 2015 instead of 3.5 per cent in the "no-AIDS" scenario (World Bank, 2001b). For the period 1986–2015, the projected average real GDP growth rate for Lesotho is 3.6 per cent instead of 4.4 per cent as projected in the "no-AIDS" scenario. This implies that the economy will be 29 per cent smaller by 2015 (World Bank, 2000).

Cuddington *et al.* (1994) extend the single-sector Solow-type model to allow for preventative and coping policies to be considered (Cuddington *et al.*, 1994: 474). This model includes additional epidemiological and demographic equations. The first additional equation is an epidemic equation that captures new HIV cases and AIDS-related deaths. The second equation captures the impact of HIV/AIDS on population growth. By simplifying these equations, they derive a single equation describing how the proportion of HIV-positive persons in the population changes over time (Cuddington *et al.*, 1994: 476–479). The authors use this model to investigate the long-term impact of condom distribution in a typical African economy (Cuddington *et al.*, 1994: 487–488). Their results suggest that prevention policies, such as a 10 per cent increase in condom use, would decrease AIDS prevalence from 31 per cent to 19 per cent (Cuddington *et al.*, 1994: 494).

Similar analysis was conducted in 2000 by the Botswana Institute for Development Policy Analysis (BIDPA). Based on the same dual labour growth model developed for Tanzania and Malawi (Cuddington & Hancock, 1995), Greener *et al.* (2000) construct a two-sector model for Botswana. Their results suggest that HIV reduces the GDP growth rate by 1.5 per year cent so that after 25 years the economy is 31 per cent smaller compared to the "no-AIDS" scenario. No change in per capita GDP is projected due to the negative impact on population growth. Unemployment among unskilled workers is projected to be 8 per cent lower. Due to the shortage of skilled workers, wages are projected to increase between 12 and 17 per cent.

An IMF working paper by MacFarlan and Sgherri (2001) applies a similar dual-economy growth model to Botswana. It predicts that GDP is likely to fall from approximately 5.5 per cent per annum in the "no-AIDS" scenario to 1.5 to 2.5 per cent a year in the "AIDS" scenario. As a result, by 2010 the economy is between 33 per cent and 40 per cent smaller compared to the "no-AIDS" scenario (MacFarlen & Sgherri, 2001: 31).

In Solow-type models the negative impact of HIV/AIDS on per capita income is offset by a decrease in labour, leading to an increase in the capital-labour ratio. Haacker (2002b) points out that in Solow growth models the underlying assumption is that an increase in the capital-labour ratio does not lead to changes in the rate of return. However, he shows that the increase in the capital-labour ratio is associated with a decline in the rate of return on capital thereby decreasing investment and capital accumulation (Haacker, 2002b: 13, 20). This worsens the negative impacts of HIV/AIDS on per capita income. Haacker (2002a) applies a Solow growth model to study the impact of HIV/AIDS for nine southern African countries. In this study, he links the rate of return on domestic assets to world interest rates. He finds that a fall in the returns to capital leads to a fall in investment opportunities. As a consequence direct foreign investment falls and capital outflows increase. The decrease in investment leads to a fall of between 4 and 10 per cent in the capital-labour ratio, which accounts for a decline in output per capita of between 4 and 10.2 per cent, depending on the country (Haacker, 2002a: 34–35).

A subsequent IMF study by Masha (2004) assesses the macroeconomic effects of prevention and increased access to health care in Botswana. The simulation period is from 2005 to 2015 (Masha, 2004: 298). The author notes that for countries in which resource extraction is a large share of GDP, it is often useful to account for this sector separately, because they are likely to be vulnerable to exogenous shocks such as changes in world prices of the extracted goods. Also, these sectors may be less sensitive to changes in domestic-factor markets because corporations may import key personnel. This consideration is relevant for Botswana, where the mining sector produces more than a third of value added in output and more than half of domestic government revenue (Masha, 2004: 298). Masha therefore assumes that the mining industry is not affected by HIV/AIDS. Mining workers who die or retire are replaced by workers from other sectors. This movement of workers will exacerbate the impact of HIV/AIDS on other non-mining sectors (Masha, 2004: 299). The results suggest that under the "with-intervention" scenario, GDP is projected to grow at an annual rate of 4.1 per cent by 2008, compared to 3.5 per cent "AIDS-without-intervention" scenario. By 2015, GDP is still growing at a rate of 4.1 per cent a year under the "AIDS-with-intervention" scenario. This is higher than GDP growth projections under the "AIDS-without-intervention" scenario, which only projects a 2.9 per cent increase in GDP but still lower than the GDP growth projections under the "no-AIDS" scenario. This scenario projects 4.9 per cent growth in GDP (Masha, 2004: 303–304).

As part of a larger study[1], BDIPA updates their earlier model by refining the investment and productivity effects in their model (Jefferis *et al.*, 2006). They simulate an "AIDS-with-ART" scenario and find that the average growth in GDP is higher than in the "AIDS-without-ART" scenario but lower than the "without-AIDS" scenario. They also find that the size of the labour force and population is higher in the "AIDS-with-ART" scenario, which leads to marginally lower GDP per capita. The lower rate of GDP growth implies that in 2021, the economy is 13.2 per cent smaller "AIDS-with-ART" compared to the "no-AIDS" scenario.

Dixon *et al.* (2001) extends the Solow model by including both educational capital and health capital variables in the production function:

$$Y_{it} = \left[A_{it} L_{it}\right]^{1-\alpha-\beta-\psi} K_{it}^{\alpha} E_{it}^{\beta} H_{it}^{\psi} \tag{E.7}$$

where Y is output, A is technology, L is the stock of labour, K is the physical capital stock, E is education and H is health capital (Dixon *et al.*, 2001: 415). Health capital is defined as:

$$h_{it} = f\left(w_{it}, m_{it}, d_{it}\right)$$

where w_{it} is a measure of material standard of living, m_{it} is per capita health care provision and d_{it} is the incidence rate of the disease (Dixon *et al.*, 2001: 416). They use this model and estimate the growth and health capital equation for 41 African countries, between 1960 and 1998. The 41 countries are divided into two groups: 16 Southern and Eastern African countries and 25 countries representing the "Rest of Africa". They find that the coefficient on health capital is significant and positive for the Rest of Africa sample and negative and close to significant in the Rest of Africa sample. They posit that this counterintuitive result may be because while most countries experience a reduction in life expectancy during the 1980s and early 1990s, data for South Africa and Swaziland (two countries with high prevalence rates) shows no reduction in life expectancy (Dixon *et al.*, 2001: 421). They find that countries in the "Rest of Africa" sample, where malaria and HIV are deemed catastrophic, health issues by OECD countries appear to be able to absorb and cope with the impact of HIV/AIDS sufficiently as to minimise the negative impact on the economy. However,

[1] Their study applies both a growth model and CGE model.

countries in the Southern and Eastern Africa sample appear unable to minimise the negative impact on the economy (Dixon *et al.*, 2001: 423).

Boucekkine *et al.* (2006) extend the Cuddington-Hancock (1994) model to account for the change in life expectancy and the subsequent impact on savings and education. They apply this model to South Africa for the period 2010–2050. Their findings show that by 2010 per capita growth is 0.1 per cent below the “no-AIDS” scenario. The gap between the “AIDS” and “no-AIDS” scenario widens and is almost triple in 2020 (Boucekkine *et al.*, 2006: 33).

Roe and Smith (2008) incorporate epidemiological projections of mortality and morbidity into a three-sector growth model and apply this model to South Africa. The simulation period is from 1993 to 2053. Their results suggest that the difference in GDP per capita range from 0.17 per cent in 1993 to 5.48 per cent in 2006. GDP “with-AIDS” is 3 per cent lower than the “no-AIDS” scenario. By 2053, the projections suggest that GDP could be over 60 per cent lower compared to the “no-AIDS” scenario (Roe & Smith, 2008: 164).

4. CGE MODELS

The first CGE analysis investigating the impact of HIV/AIDS was conducted by Kambou, Devarajan and Over (1992). Kambou *et al.* (1992) construct an 11-sector CGE model for Cameroon, based on a 1979–1980 SAM, and analyse the impact of HIV/AIDS on economic growth via a reduction in labour supply. They chose Cameroon for two reasons. Firstly, most sub-Saharan countries are characterised as resource poor. Their development process is hampered by a small pool of skilled workers and by chronic foreign exchange shortages. Secondly, epidemiological evidence shows a rapid increase in AIDS infection among the urban, educated and highly trained segment of the labour force. The concern is that if AIDS disproportionally affects skilled labour, future economic development can be undermined (Kambou *et al.*, 1992: 111).

To analyse the impact of HIV, they decrease labour supply uniformly across all labour groups. They reduce labour supply by 30,000 workers, which is equivalent to a 0.8 per cent reduction in the labour force. The simulations are carried out under the assumption of no government intervention. The reduction in labour supply is simulated using both a static and a dynamic model. The results from the static model show a decline in GDP, investment, lower exports and import demand, lower government savings and a deterioration of public finances (Kambou *et al.*, 1992: 116). In the dynamic simulation the baseline forecast represents the economy with “no-AIDS”. In the absence of AIDS, GDP grows by 4.3 per cent with investment the main contributor to GDP growth. Investment growth is driven by the increase in savings. Exports grow on average by 6 per cent. The authors again simulate a reduction in labour supply due to HIV/AIDS by using a dynamic model. Their results show that the economy is affected via three mechanisms: (1) the economy is adversely affected by the AIDS epidemic via the reduction in labour supply. The impact on GDP is greater the larger the share of labour in production and the ease with which labour can be substituted with other production factors; (2) lower government revenues and lower private savings cause the level of aggregate savings to fall, which decreases investment and adversely affects GDP; and (3) the reduction in labour supply increases the real wage, leading to higher domestic production costs, which leads to international competitiveness to deteriorate. This leads to lower exports, lower GDP and lower employment levels (Kambou *et al.*, 1992: 122–123). The fall in GDP is mostly due to the reduction in skilled labour. The paper concludes that it is the distribution of HIV/AIDS across skill groups rather than the size of the HIV epidemic that is important in determining the overall impact of HIV.

Arndt and Lewis (2000) construct an economy-wide dynamic CGE model for South Africa to analyse the impact of HIV/AIDS on the economy and particularly on total factor productivity. Their model includes 14 productive sectors including three service sectors (medical and health, social and government services) relevant to HIV/AIDS. There are five primary factors (professional, skilled labour, unskilled labour, informal labour and capital), five household categories representing income distribution quintiles and seven government functional spending categories (Arndt & Lewis, 2000: 382). In this study, productivity can impact output via changes in overall productivity and the contribution of factor-specific inputs such as labour. They put four reasons forward why they believe total factor productivity growth rates will be negatively affected. Firstly, resources directed toward the diseases by government, universities and firms are large and involve opportunity costs. Secondly, AIDS will generate high labour force disruption due to absenteeism and higher turnover rates. Thirdly, transaction costs in enforcing contracts are likely to increase as HIV-positive borrowers may see no reason to maintain their debt payments. Finally, the receptivity of the workforce to implementing improved processes may be curtailed because of the severity of the epidemic (Arndt & Lewis, 2000: 385).

Their “no-AIDS” baseline forecast postulates relatively low average growth rates during 1997 to 1999. The main drivers of the growth are capital and an increase in the rate at which professional and skilled labour accumulates (Arndt & Lewis, 2000: 388). Their “AIDS” scenario starts off at the same level as the “no-AIDS” scenario because of low incidence rates recorded at the start of their study. Thereafter, the percentage difference in growth paths is significant. The year-on-year percentage difference between the “AIDS” and “no-AIDS” scenario peaks at 2.6 per cent in 2008. The cumulative percentage difference suggests that real GDP is 17 per cent lower in 2010 relative to the baseline scenario (Arndt & Lewis, 2000: 388). A decomposition of the percentage change in GDP growth shows that total factor productivity contributes 34 per cent, labour supply 13 per cent, factor-specific productivity 8 per cent and government savings 45 per cent (Arndt & Lewis, 2000: 387).

As the economy shrinks, one may expect the size of the population to fall due to AIDS-related mortality. It is therefore possible that per capita GDP may increase. However, the authors find that per capita GDP falls by approximately 8 per cent. The simulation results further suggest that although AIDS impacts unskilled labour the most, the net effect of higher AIDS mortality and slower growth leaves the unemployment rate among unskilled workers largely unchanged (Arndt & Lewis, 2000: 387).

In a second paper based on the same model, Arndt and Lewis (2001) focus on the sectoral impact of HIV/AIDS. They find that all sectors are affected negatively with the greatest impact on the Construction and Equipment sectors. A characteristic of these sectors is that investment demand accounts for 62 per cent and 34 per cent of total demand in the respective sectors. With such high investment shares, these sectors are sensitive to the decrease in savings. On the other hand, medical services and government services are not so severely affected by the epidemic. These services sectors are the least affected due to the increase in demand for the output that these sectors produce. In terms of employment, labour-intensive sectors are severely affected by the epidemic, with the demand for unskilled and semi-skilled labour falling. The decrease in labour demand is completely offset by the decline in supply. As a result, unemployment rates are essentially the same between the "AIDS" and "no-AIDS" scenarios (Arndt & Lewis, 2001: 442–443). They also find that a policy of real wage moderation has a significant impact on GDP growth. Their simulation results suggest that if real wages remain constant over the simulation period, GDP growth performance improves by 0.5 per cent relative to the "no-AIDS" simulation. If the real wage declines at a rate of 1 per cent per year, annual growth performance improves by nearly 1 per cent. The improvement in growth is due to higher employment, which increases investment. The authors find that when real wages fall by 1 per cent per annum, unemployment falls from 58 per cent in the baseline to 41 per cent (Arndt & Lewis, 2000: 444).

Löfgren *et al.* (2004) use a dynamic CGE model, calibrated to a 2001 SAM, to assess the impact of policies in accelerating growth, improving household welfare and reducing poverty for the Zambian economy (Löfgren *et al.*, 2004: 8). The simulation period is from 2002 to 2015.

Their base scenario includes HIV/AIDS projections on the population and labour force growth. They therefore include, in the baseline, the projected effects of HIV/AIDS on the accumulation of human capital and overall mortality (Löfgren *et al.*, 2004: 32). Their first simulation assesses the impact of removing the effects of AIDS without requiring the government to increase its level of health spending, that is, they effectively construct a "no-AIDS" scenario. By comparing the "AIDS" and "no-AIDS" scenarios, they estimate that HIV/AIDS leads to a 0.9 per cent reduction in annual GDP growth. They find that an increase in factor growth rates and total factor productivity increases production, which increases the level of GDP. In the absence of HIV/AIDS, the Zambian economy would have grown at an annual rate of 5 per cent. The agricultural sector benefits the most because it is relatively labour intensive, employing workers with little or no education (Löfgren *et al.*, 2004: 47–48). The second simulation (Public Financed Treatment scenario) assumes that half of the infected population receives treatment, with the government bearing the full cost of this program. This amounts to 650,000 people receiving treatment at a total cost of 7.1 per cent of GDP. The increase in spending increases total government spending by 50 per cent. Since only half of infected people are treated, the increase in population, labour force and total factor productivity is only half of the results in the previous simulation. The authors find that the positive effect on the increase in labour supply is outweighed by the cost of the treatment program. Government consumption increases from 3 per cent in the base scenario to 6 per cent in the Public Financed Treatment simulation. The results further suggest an increase in investment, import demand and exports but no growth in private consumption. At the sectoral level, GDP growth is spread across the main sectors (Löfgren *et al.*, 2004: 48–49). The agricultural sector grows the fastest due to the increase in exports. The manufacturing sector benefits due to the increase in government spending and investment. The third simulation (Balanced Budget scenario) models the treatment of 50 per cent of infected people, financed by an increase in direct tax rates on domestic institutions. They find that government consumption increases by the same percentage as in the previous simulation but this increase is offset by an increase in taxes. The average tax rate on households increases from 8.5 per cent to 12.4 per cent. The increase in tax rates for high-income groups leads to a fall in their level of consumption and savings. There is no change in the budget deficit and therefore no crowding-out of investment. Rural households benefit the most in this simulation because of higher labour force growth and their exclusion from financing the treatment program (Löfgren *et al.*, 2004: 50). The final simulation (HIPC-Funded AIDS scenario) models the financing of the AIDS treatment program with the funds saved by the government due to debt relief. In this simulation only 14 per cent of the infected population receives treatment financed through debt relief funds. The results show that there is a slight increase in the population, labour force, total factor productivity and government spending. In this simulation, the increase in government spending does not lead to an increase in the budget deficit. As a result, private consumption per capita increases for all household groups. Overall the results in this simulation are very small given the scope of this program (Löfgren *et al.*, 2004: 51).

Dixon *et al.* (2004) report preliminary results from a study that applied a CGE model to Botswana. Their model includes an embedded epidemiological model to examine interventions aimed at reducing sexually transmitted diseases (STDs) and a health education program that reduces the number of new sexual partnerships being formed. Their model is a version of the IFPRI standard model and is calibrated to the 1993/1994 national accounts. The model simulation runs from 1994 to 2020 with the interventions introduced in 2000. Without intervention the epidemic reduces per capita disposable income by as much as 50 per cent over the simulation period. Their simulation results suggest that interventions such as STD treatment and a reduction in the number of sexual partners have positive benefits, which may reduce the fall in income by at least half.

As part of the larger BIDPA study, Jefferis *et al.* (2007, 2008) applies a dynamic CGE model for Botswana, which is calibrated to the 2002/2003 SAM. This model is updated with an annual demographic projection of population growth by age and gender. Labour supply is estimated based on the demographic projections and reflects the prevalence rates of different occupational groups and regions. The dynamic model is solved for the 2003–2021 period. The authors model three scenarios. The first is a base case scenario, which includes AIDS, that is, “with-AIDS” scenario. The second simulation reflects an environment without AIDS and the third simulates the HIV epidemic with ART treatment. The results show that in the absence of treatment, current growth is unlikely to reduce poverty and that rural areas are the most severely affected. AIDS reduces economic growth by approximately 1.6 per cent per annum. This is a 25 to 30 per cent reduction in the size of the economy in absence of ART by 2021. AIDS also limits economic diversification especially into more labour-intensive sectors. The negative impact on labour-intensive sectors, such as the mining sector, is responsible for most of the decline in growth over recent years. As a consequence, the national poverty rate is 2 per cent higher in 2021 with an additional 43,000 uninfected people forced into poverty. The rural poverty rate rises in the absence of AIDS because the increase in labour supply is offset by weaker employment opportunities.

With the introduction of the treatment program, the negative impacts of HIV/AIDS can be mitigated. Apart from decreasing the mortality rate, providing treatment reclaims a quarter of the decline in growth and a third of the poverty caused by AIDS. Financing of the treatment program crowds-out investment and limits growth in non-mining industries. Those who are employed and come from higher-income households benefit the most, thereby increasing inequality (Jeffris *et al.*, 2007: 107–108).

Chant (2008) examines the causal chain between anti-retroviral treatment (ART) and economic growth under different scale-up assumptions. In this study, an augmented Markov transition model is integrated with an epidemiological model of HIV/AIDS and a CGE model for South Africa. The effects of HIV/AIDS on human capital accumulation are endogenously determined. These transition matrices show the impact of HIV/AIDS on human capital accumulation for South Africa and the dynamics of education and skill formation from 2000 to 2005 (Chant, 2008: 255). By linking the demographic outputs to the transition matrices, the impacts of various policies are tested with a CGE model. The baseline scenario is one where HIV/AIDS is present and constant at the 2006 levels of ART. Results from the simulations indicate the increasing ART leads to a higher level of growth and per capita GDP. GDP is 5.8, 6.4 and 6.8 per cent higher when 60, 80 and 100 per cent respectively of new AIDS cases receive treatment. The positive effects come from an increase in employment. Further results show that the number of children in education increases by 1.4 per cent relative to the base case. The growth in the population exceeds the growth in GDP so that GDP per capita is lower given the higher level of ART. In this study the projection period is too short to show the impact of an increase in the number of educated workers on labour supply. The author further finds that the financing of the ART program reduces the positive impact on GDP. The reduction is greatest when treatment is financed with overseas aid and smallest when households finance the ART program through an increase in income tax.

Our final CGE study under review is that of Thurlow *et al.* (2009). This study uses a regional model to determine the economic impact of HIV/AIDS in two regions in South Africa: KwaZulu-Natal (KZN) and the rest of South Africa. In this study they incorporate surveys of workers' HIV prevalence, results from a demographic model and a regionalised economy-wide model linked to a micro-simulation model. Two simulations are conducted for the period 2002–2025. In the "AIDS" scenario they capture the current growth path of KZN and of South Africa by incorporating demographic projections for labour supply and observed trends for total factor productivity (TFP) and labour productivity. In a hypothetical "no-AIDS" scenario they adjust their forecast to include higher population, labour supply and productivity growth rates (Thurlow *et al.*, 2009: 7). The authors find that HIV/AIDS reduces KZN's overall population growth rate from an average of 1.85 per cent from 2002 to 2025 in the "no-AIDS" scenario, to 0.79 per cent in the "AIDS" scenario. They note that the decline in labour supply is larger than the decline in population. This reflects the concentration of HIV among the working age population. In the "AIDS" scenario labour productivity grows at 1.8 per cent, which is lower than in the "no-AIDS" scenario where labour productivity grows at 1.92 per cent. Industries most adversely affected by HIV are the electrical machinery and electricity industries. The electrical machinery sector is labour-intensive and more vulnerable to changes in labour supply. This industry mainly employs lower skilled workers who are most affected by HIV/AIDS. In addition, food products and textiles have lower-income elasticities and thus a fall in income generates larger declines in the demand for electrical machinery than food or textiles (Thurlow *et al.*, 2009: 9). The GDP growth rates for KZN and the rest of South Africa are 1.6 and 1.42 per cent lower respectively than in the "no-AIDS' scenario. This implies that over the simulation period, the economies of KZN and the rest of South Africa are 43 and 37 per cent smaller in 2025 than they would have been in the absence of AIDS (Thurlow *et al.*, 2009: 12).

5. OTHER MODELS AND METHODS

5.1. Overlapping-generations model

Overlapping-generations models have been used to examine the long-term impact of HIV/AIDS over generations. Bell *et al.* (2006) use a two-generation (childhood and adulthood) model and apply it to South Africa for the period 1960–2080. This model captures the impact of higher mortality on the formation of human capital through three channels: (1) when parents die or become disabled, children have less productive capacity because less human capital is transmitted; (2) when one or both parents die there is a loss of income that negatively impacts on children's schooling; and (3) as a consequence the children of AIDS victims become adults with little or no education, which makes them less able to invest in their own children (Bell *et al.*, 2006: 57). The simulation results suggest that in the absence of any intervention, the South African economy could shrink to half its current size in about four generations (Bell *et al.*, 2006: 55).

5.2. HIV/AIDS models

A number of HIV/AIDS models have been developed to simulate the impact of HIV incidence and prevalence on the demography of a population. These models often include a behavioural component which allows for the estimation of how HIV spreads through the population and who is vulnerable in contracting HIV. Outputs of these models are used as inputs into macroeconomic and CGE models (Bloom & Mahal, 1997; Jeffris *et al.*, 2007; Chant, 2008).

HIV/AIDS models can either be stochastic or deterministic in their nature (Centre of Actuarial Research, 2011). Examples of stochastic models include the SimulAIDS model (Robinson *et al.*, 1997) and STDSIM (Korenromp *et al.*, 2002). Robinson *et al.* use the SimulAIDS model to estimate the proportion of HIV infections attributed to STD in rural Uganda. The SimulAIDS model simulates a population with a set of characteristics. These include age, type of sexual partnership and the identity of all sexual partners. During simulations events occur with given probabilities and the status of the entire population is updated (Robinson *et al.*, 1997: 181). Korenromp *et al.* use STDSIM to simulate the spread of HIV and four bacterial and one viral STD. STDSIM simulates the natural history and transmission of a number of STDs and HIV in a population. The population is defined by a set of parameters, and characteristics that may change over time. The formation of heterosexual partnerships between individuals and the transmission of STDs are modelled as stochastic events (Korenromp *et al.*, 2002: 56).

Deterministic models include simulation-type models and curve-fitting models. An example of a simulation model is the ASSA model (Johnson & Dorrington, 2006; Dorrington *et al.*, 2005). Curve-fitting models include the EPP/Spectrum packages (Stover, 2004).

The Actuarial Society of South Africa (ASSA) developed a demographic and epidemiological model for South Africa. The version applied in this thesis is the ASSA2003 model (hereafter the ASSA model): see Dorrington *et al.* (2005) and Johnson and Dorrington (2006) for a full description of the ASSA model. A brief summary of the main features of the ASSA model is given below.

This model projects annual changes in the population profile over a number of years given a number of demographic, epidemiological and behavioural assumptions. The model splits the population by gender and race into three age cohorts: young (0–13), adult (14–59) and old (60+). HIV is spread through heterosexual activity and therefore the adult groups are further split into four risk groups reflecting their level of exposure to the risk of contracting HIV (Dorrington *et al.*, 2005: 6).

The spread of the virus is modelled by taking into account the following variables: vulnerability from partner being in a specific risk group; change in the stage of the disease of their partner; number of new partners in a year; number of contacts per partner; and the probability of contracting the virus depending on the use of condoms.

The ASSA model allows for five interventions to be modelled. Each intervention is based on several assumptions that can be altered. They are (Dorrington *et al.*, 2005: 16–17):

- Improved treatment for sexually transmitted diseases (STDs)
- Information and education campaigns (IEC) and social marketing
- Voluntary counselling and testing (VCT)
- Mother-to-child transmission prevention (MTCTP)
- Anti-retroviral treatment (ART).

The full version of the model provides the following outputs (Dorrington *et al.*, 2005: 20):

- Numbers of people in each sex/risk group/HIV classification and in total
- Number of deaths in each year due to AIDS or non-AIDS reasons
- Fertility and birth rates
- Male and female mortality rates by age
- Crude extra mortality i.e. additional mortality resulting from AIDS
- Number of people accessing prevention and treatment programs
- Number of adults and children in different stages of HIV disease.

The model includes the WHO Clinical Staging System through which a person progresses before dying of AIDS. The effects of anti-retroviral treatment are modelled by including two additional stages reflecting those who receive treatment and those who started treatment but discontinued it. Stages 1 and 2 are largely asymptomatic. Symptoms occur more frequently in Stage 3 while people in Stage 4 suffer severe conditions that are collectively referred to as AIDS (Dorrington *et al.*, 2005: 12). The ASSA model is calibrated to the antenatal prevalence data for 2003, mortality data for 2002–2003 and data from the 2002 Nelson Mandela/Human Sciences Research Council household survey and the Reproductive Health Research Unit survey of sexual behaviour and prevalence (Dorrington *et al.*, 2005: 3).

The ASSA model is also adapted for demographic analysis in Botswana. The underlying theory of the model is the same but the model is calibrated to Botswana data, including sentinel surveys, the BAIS II, and the national population and household census (Jefferis *et al.*, 2007: 18).

The UNAIDS/WHO Estimation and Projection Package (EPP) uses surveillance data to estimate the trends of national adult incidence and prevalence over time (Brown *et al.*, 2006, 2008; UNAIDS/WHO, 2009:4).[2] This program fits a curve to available surveillance data to estimate the HIV prevalence trends over time for both concentrated and generalised epidemics. For generalised epidemics EPP estimates the trend in HIV prevalence by fitting an epidemiological model to surveillance data. The general way of modelling generalised heterosexual epidemics is to divide the population by geographic subdivisions such as provinces. EPP allows for separate HIV trends to be created for each of the geographical divisions. These individual curves are then combined to produce a national estimate of HIV prevalence over time. The UNAIDS reference group on Estimates, Modelling and Projections decided that a model with four parameters is suited in fitting the HIV epidemic curves (UNAIDS/WHO, 2009: 5). The four parameters are:

- $t0$ refers to the start year of the epidemic;
- r is the force of the infection. A large value for r will cause the prevalence rate to increase rapidly while a small value for r will cause a slow increase in the prevalence;
- $f0$ is the initial fraction of the adult population at risk; and
- ϕ is a behavioural parameter. This parameter shows how the proportion of new entrants in the adult population at risk of infections may change over time. A negative ϕ implies that people reduce their

[2] A full description on the model theory, how to prepare the data for the model and how to use the model to develop epidemic curves are documented in "Estimating national adult prevalence of HIV-1 in generalised epidemics" (UNAIDS, 2009).

risk of becoming HIV positive. The impact of a negative ϕ is that the fitted curve shows a sharper decline after the peak is reached. If ϕ is zero, the proportion of new entrants at risk remains constant and the prevalence declines after the peak is reached. Prevalence declines as people die. If ϕ is positive, the risk increases over time and the prevalence will stabilise at a high level (UNAIDS/WHO, 2009:5).

The Spectrum package is a suite of programs that is used to examine the consequences of current trends and future program interventions on the dynamics of a population. At the core of Spectrum is a model called DemProj which is used for demographic projection of the population by age and gender. Other programs that are part of the Spectrum package include AIM, FamPlan and RAPID. These programs are used in conjunction with DemProj. FamPlan is used to project family-planning needs while RAPID models the socio-economic costs of high fertility. AIM is used to examine the demographic and social impacts of HIV/AIDS. The Spectrum package provides outputs on the number of people living with HIV/AIDS by gender and age, number of AIDS deaths and number of orphans as a consequence of AIDS (Stover, 2004; UNAIDS, 2011).

Morris and Kretzschmar (1997) developed a model to estimate the spread of HIV through the population. The purpose of this model was not so much to model the demographic impact of HIV/AIDS but rather to explain specific behaviour, in this case concurrent partnerships, why the rate of infection is higher in some countries and population groups. They use modelling techniques to compare the spread of HIV in two populations, one where people are in monogamous relationships and the other where people are in long-term concurrent relationships. Their results suggest that concurrent partnerships exponentially increase the number of infected individuals and the growth of the epidemic in the initial phase (Morris & Kretzschmar, 1997). They conclude that concurrent partnerships can be as important as multiple partnerships in amplifying the heterosexual spread of HIV in some countries.

5.3. Cost analysis

Of special interest to the South African Treasury is the future estimated cost and financing implications of the HIV epidemic. In a recent study, Guthrie *et al.* (2010: 1) estimate the impact of several intervention scenarios on the magnitude, nature and cost of national response to HIV/AIDS in South Africa. They describe three possible scenarios of future ART scale-up programs. Based on assumed coverage rates and unit costs, each program impacts on the size of the infected population and the costs associated with these programs. The Resource Needs Model (RNM) is used to determine the costs of the different scenarios. Three types of costs are: prevention, treatment and mitigation and support costs.

The first scenario is the "Narrow" scenario, which represents the current South African interventions and assumes that the targets of the national Strategic Plan (NSP) are reached by 2011. There projections show a steep increase in the prevention cost from 2007 to 2011 if the targets are to be met by 2011. The highest prevention costs are associated with youth and workplace programs as well as mother-to-child transition. Expenditure on condoms is surprisingly low. Treatment costs are largely made up of ART costs while mitigation costs consist of family and home support (Guthrie *et al.*, 2010: 42–44).

The second scenario is the "Expanded NSP" scenario and assumes that higher treatment targets are met. This scenario expands on the range of prevention programs to include male circumcision and greater community mobilisation, and investment in social programs for vulnerable groups. This approach focuses on interventions aimed at addressing the causes of vulnerability in contracting HIV, as well as scale-up of treatment programs. It is assumed that the targets are met by 2021 except for new treatment targets, which are assumed to be met by 2015. The prevention costs include additional efforts to reduce vulnerability to the infection through programs aimed at addressing issues such as gender-based violence. Prevention costs include workplace programs, community mobilisation and VCT requirements. In terms of treatment costs, this scenario assumes that a new ART regime is introduced. This new regime incorporates a lower unit cost compared to the unit cost considered in other scenarios. Again ART costs make up the bulk of the projected AIDS spending. This scenario projects a steep increase in the costs associated with mitigating the impact of HIV (Guthrie *et al.*, 2010: 44–47).

The third scenario is the "Hard choices" scenario and assumes that the coverage of some programs is scaled up while other programs are scaled down. The focus of this scenario is on the most cost-effective prevention interventions (Guthrie *et al.*, 2010: 19–20). Under this scenario costs are cut back on programs for community mobilisation, mass media, workplace and palliative care (Guthrie *et al.*, 2010: 47–48).

In summary, all three scenarios suggest that future AIDS spending will increase rapidly. The expanded NSP scenario is the most expensive of the three scenarios and the "Hard choices" scenario the cheapest. The authors conclude that government can obtain greater value for money by choosing prevention programs that are cost-effective (Guthrie *et al.*, 2010: 48–49).

5.4. Sector-specific analysis

Sector-specific analysis provides an overview of the severity of the epidemic in a sector, the characteristics of those who are HIV positive, and the sector-specific *response* to the epidemic. Often these projects or studies are not available in the public domain. For South

Africa three sector-specific analyses are briefly described below.

One of the first sector-specific studies was published by Morris *et al.* in 2000. Their study includes rural and predominantly male sugar mill workers living in KwaZulu Natal (KZN). They find that 26 per cent of the workers tested were HIV positive. The age group with the highest number of infected people is that between 35 and 44 followed by the 25–34 age group. HIV-positive workers are primarily unskilled and semi-skilled labourers and are predominantly part of the lowest two pay bands. The study finds that 5.7 per cent of the workers had taken early retirement due to HIV morbidity and that HIV-related deaths amount to approximately 5 per cent of the sector's workforce. The last two years of employment of an HIV-positive person are when additional costs are incurred by the employer in terms of absenteeism, productivity loss and medical costs (Morris *et al.*, 2000: 416–417).

A study by Bowen *et al.* (2008) analyses the degree of association between risk factors and HIV prevalence in the construction sector. The construction sector has one of the highest prevalence rates in South Africa. Their study includes the results of 10,243 HIV tests of construction workers employed in 55 companies. The risk factors considered include age, nature of employment, occupation and geographical region of employment. The results suggest that in terms of the nature of employment, those who are permanently employed and contracted per hour have the highest HIV prevalence rates at 18 per cent. The lowest HIV prevalence rate is registered for those employed as students (Bowen *et al.*, 2008: 829). In terms of age, HIV prevalence is the highest for the 30–39 age cohort at 23 per cent, followed by the 40–49 age group at 18 per cent. In terms of occupation, operators and drivers had the highest prevalence at 21 per cent followed by skilled construction workers at 19 per cent. Those employed as administrators and managers had the lowest prevalence at less than 1 per cent (Bowen *et al.*, 2008: 830). KwaZulu Natal is the region with the highest prevalence rate at 29 per cent followed by the Free State at 25 per cent. The Western Cape has the lowest prevalence rate at 9 per cent (Bowen *et al.*, 2008: 831). The study finds that the response and interventions in this sector are limited to HIV awareness (Meintjes *et al.*, 2007: 255).

A study by Shisana *et al.* (2004) analyses HIV results in four provinces to determine HIV prevalence among health care workers. The results suggest that in 2002, 15.7 per cent of employed health workers were living with HIV. HIV prevalence is the highest for health workers aged 18–35 at 20 per cent. HIV prevalence for professional and non-professional health workers is 13.7 per cent and 20.3 per cent respectively (Shisana *et al.*, 2004). The authors note that high prevalence has serious implications for the health care system. Firstly, sick health care workers will not be able to perform their duties. Secondly, HIV-negative workers will be overloaded with work as they fill in for their sick colleagues. Finally, due to the nature of their work, health care workers face an increased risk of exposure to the HIV virus (Shisana *et al.*, 2004: 850).

The final study under review is that of Evian *et al.* (2004). In this study they analyse 34 workforce surveys to determine HIV prevalence among formally employed people. These surveys include 44,000 employees and were conducted in South Africa, Botswana and Zambia in 2000–2001. The national HIV prevalence for the entire sample is 16.6 per cent with the highest rates reported in Botswana (24.6 per cent) followed by Zambia (17.9 per cent) and then South Africa (14.5 per cent). The authors find that the mining sector has the highest prevalence rate. In terms of the type of workers, contract workers, such as cleaners, security guards and food service employees, have the highest prevalence rates. The authors state that these workers are vulnerable because they are unskilled or semi-skilled, live away from home and do shift work. For managers and skilled workers, the prevalence rates are much lower at 4.5 and 10.5 per cent respectively (Evian *et al.*, 2004: 129).

6. CONCLUDING REMARKS

This paper describes different methods and models used in analysing the impact of HIV/AIDS in a number of countries. Although these studies use different methods, the consensus is that HIV/AIDS affects economic growth negatively. However, the magnitude of the negative impact of the epidemic is dependent on the country-specific prevalence rates in the population and the distribution of HIV/AIDS among the labour force especially over skill. In general we find that countries with high HIV prevalence rates are more severely affected than those with lower HIV prevalence. Also, the financing of prevention and intervention programs will have a serious impact on public spending.

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