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Developing a Baseline Forecast for a South African Dynamic CGE Model (SAGE-H) with HIV/AIDS Detail

by

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The Centre of Policy Studies (COPS) is a research centre at Monash University devoted to economy-wide modelling of economic policy issues.

Developing a baseline forecast for a South African dynamic CGE model (SAGE-H) with HIV/AIDS detail.

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Policy analysis with a detailed CGE model requires two simulations. The first simulation is the baseline forecast or business-as-usual simulation. This simulation models the growth of the South African economy and the HIV epidemic over time in the absence of the policy change under consideration. The second simulation is the policy simulation. This simulation generates a second forecast that incorporates all the exogenous features of the baseline forecast, and now includes policy-related shocks reflecting the details of the policy under consideration. The impacts of a policy are typically reported as a percentage deviation away from the baseline forecast.

This paper describes the baseline forecast developed for a South African dynamic computable general equilibrium (CGE) model (SAGE-H). SAGE-H is a large-scale dynamic CGE model of the South African economy which consists of two inter-dependent modules. The first module contains core economic theory and the second module contains the detailed modelling of labour supply including HIV detail. To gain a better understanding of the main features of SAGE-H, I follow the approach of Dixon and Rimmer (2002) by first developing a stylised back-of-the-envelope (BOTE) model. The BOTE model captures the underlying features and macroeconomic relationships in SAGE-H. In this paper I use the BOTE model to (1) explain the closures developed for the baseline simulation and (2) aid with the interpretation of the main macro results produced in the baseline simulation. Use of miniature models such as BOTE to describe the results from a full-scale applied economic model has a long-tradition in CGE modelling (Dixon *et al.*, 1984).

I use the BOTE model to describe the closure settings and results of the baseline forecast. The simulation period is from 2003 to 2045.[1] The baseline forecast includes three different closures. The first closure, Forecast closure 1 (hereafter FC1), is developed to accommodate observed macroeconomic data for the period 2003–2009. I also introduce data to show the change in the number of new HIV cases over this period. The second closure, Forecast closure 2 (hereafter FC2), is developed to accommodate independent forecast data for selected macroeconomic variables. This closure is used for 2010 to 2014. The third closure, Forecast closure 3 (hereafter FC3) is developed for the years 2015 to 2045. For this period no independent forecast data are available.

[1] HIV/AIDS is a slow-progressing disease with the impact of the disease only realised in the long run. The simulation period is long enough to allow the model to adjust to the imposed policy shocks and produce a solution in which the economy moves to a new steady state under the policy scenario.

This paper is set out as follows: Section 1 gives a broad overview of SAGE-H. Section 2 describes the equations in the BOTE model that underlines the main macro mechanisms in SAGE-H. I also describe a valid short-run closure for the BOTE model. In developing an appropriate closure for the BOTE model, I distinguish between equations describing economic relationships within any given year, equations describing the underlying theory of how adults change their HIV status at the start of any given year, equations describing the start-of-the-year stock variables, and an equation describing the wage adjustment mechanism. The short-run closure serves as the starting point in developing the appropriate baseline forecast closure, described in Section 3. The paper ends with concluding remarks in Section 4.

Keywords: Computable general equilibrium (CGE), Africa, HIV/AIDS

JEL Classification: C68, I190, O55

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LIST OF ABREVIATIONS

BOTE	Back-of-the-envelope model
FC1	Forecast closure 1
FC2	Forecast closure 2
FC3	Forecast closure 3
HIV	Human immunodeficiency virus
LFS	Labour Force Survey
SAQB	South African Reserve Bank Quarterly Bulletin
SARB	South African Reserve Bank

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1. OVERVIEW OF SAGE-H

SAGE-H is a large-scale dynamic computable general equilibrium (CGE) model of the South African economy. SAGE-H consists of two inter-dependent modules. The first module describes the behaviour of industries, investors, households, government and exporters at the national level, and is based on the theoretical structure of the MONASH model (Dixon and Rimmer, 2002). The second module describes labour supply, and is based on the theory described in Dixon and Rimmer (2003, 2009).

SAGE-H models production of 28 commodities by 28 industries. Three primary factors are identified: land, capital and labour. Labour is further distinguished by 11 occupational types. The model has one representative household and one central government. Optimising behaviour governs decision-making by the household and firms. Industries minimise costs subject to given input prices and a constant returns to scale production function. The household is assumed to be a budget-constrained utility maximiser. Units of new industry-specific capital are cost minimising combinations of South African and foreign commodities. We assume that domestic and imported varieties of commodities are imperfect substitutes for each other, with this modelled via constant elasticity of substitution (CES) functions. The export demand for any South African commodity is inversely related to its foreign-currency price. SAGE-H models the consumption of commodities by government as well as direct and indirect taxes. All sectors are competitive and all commodity markets clear. SAGE-H recognises five main types of dynamic adjustment: capital accumulation, net foreign liability accumulation, public sector debt accumulation, labour force movements between labour market states via transition matrices and labour market offers, and short-run stickiness in wage adjustment. Capital accumulation is industry-specific and linked to industry-specific net investment. Changes in industry-specific investment are linked to changes in industry-specific rates of return. Changes in net foreign liabilities are linked to changes in the current account balance, and changes in public sector net debt are linked to changes in the government deficit.

The model's HIV detail is expressed in the labour supply theory. This theory imposes a stock/flow dynamic mechanism on labour market groups distinguished by labour market activity, age, gender, race, and HIV status and, if positive, HIV stage. Broadly, the theory specifies that at the start of year t, people aged 15-65 (the working age population, hereafter the WAP) are divided into categories based on common characteristics. These characteristics are age, gender, race, HIV status/stage and labour-market activity in year t-1. People in categories offer their labour services to activities performed during year t. At the end of year t, people still part of the WAP progress one year in age and may change their HIV status/stage. Some people leave the WAP due to retirement or death. After this transition, people are again grouped into categories, based on common characteristics. The process of labour supply from a category to an activity is then repeated.

2. A STYLISED VERSION OF SAGE-H: THE BACK-OF-THE-ENVELOPE (BOTE) MODEL

The BOTE model is presented in Table 1. We distinguish between equations that describe:

- economic relationships within any given year of our year-on-year simulations (B.1–B.16);
- how the HIV status of adults changes between years (B.17–B.20); and
- movements in economic stock variables between years (B.21–B.22).

Note that the presentation of the BOTE equations in Table 1 renders in bold those variables that are exogenous in the short-run closure of the model. Equations (B.1) to (B.22) are relevant to both the basecase and policy simulations. These equations are described below.

Equation (B.1) describes real gross domestic product (*GDP*) from the expenditure side in constant price terms. Equation (B.2) describes an economy-wide constant returns-to-scale production function, relating real GDP to inputs of capital (*K*), labour (*LD*) and primary-factor technical change (*A*). Equation (B.3) relates the sum of private and public consumption to gross national income (*GNP*) via a given average propensity to consume (*APC*). Equation (B.4) defines the ratio of public to private consumption (Γ). Equation (B.5) defines real GNP as GDP adjusted by a positive function of the terms of trade (TOT) less interest payment on real foreign debt. Equation (B.6) relates aggregate import volumes to GDP, the terms of trade (*TOT*) and an import-domestic twist variable ($Twist^{pref}$). (B.6) summarises the SAGE-H assumption that agent-specific demand for an individual import is positively related to the agent's activity level (proxied by GDP in B.6) and negatively related to the price of the import relative to the price of the domestic substitute (proxied by the terms of trade in (B.6)). Import demands are also positively related to autonomous shifts in users' preferences towards imports (proxied in B.6 by $Twist^{pref}$). Equation (B.7) defines the terms of trade (TOT) as the ratio between the export price index and import price index. In SAGE-H, the export volume for any individual commodity is negatively related to its foreign-currency price via a constant elasticity export demand function. At the economy-wide level, we summarise this in BOTE via (B.8). Equation (B.9) makes investment a positive function of the rate of return on capital (*ROR*). Equation (B.10) defines the ratio of investment to capital, which is the gross capital growth rate. Since the production function is constant returns to scale, marginal product functions are homogenous of degree zero and can be expressed as functions of the *K/LD* ratio and A. Equation (B.11) relates the profit-maximising *K/LD* ratio negatively to the rate of return on capital (*ROR*) and a labour-capital twist variable ($Twist^{lk}$), and positively to technological change (*A*) and the terms of trade (*TOT*). Equation (B.12) relates the real consumer wage (*W*) to changes in the capital-labour ratio (*K/LD*), technological change (*A*), the terms of trade (*TOT*) and the capital-labour twist variable ($Twist^{lk}$).

Equation (B.13) equates labour demand (*LD*) and labour supply (*LS*). Equation (B.14) defines start-of-year labour supply (*LS*) as the sum of HIV-negative workforce participants ($LS^{\mathrm{HIVn}} \times ER^{\mathrm{HIVn}}$) and HIV-positive workforce participants ($LS^{\mathrm{HIVp}} \times ER^{\mathrm{HIVp}}$). Note that (B.14) distinguishes the employment rates of HIV-negative and HIV-positive workforce participants because SAGE-H recognises that HIV-positive people make weaker offers to employment activities relative to HIV-negative people. Equations (B.15) and (B.16) set HIV status-specific employment rates (ER^{HIVn}, ER^{HIVp}) equal to the product of a general employment rate shift variable (*FER*) and HIV status-specific shift variables (FER^{HIVn}, FER^{HIVp}).

To understand how the components in (B.14) are determined, it may be helpful to first consider the interpretation of Equations (B.17) to (B.20). These equations determine year-on-year movements in labour supply, distinguished by HIV status. In the BOTE framework, an HIV-negative adult in year $t-1$ has three transition probabilities:

- They might survive and change their HIV status from HIV negative to HIV positive at the start of year t. In BOTE we represent this probability by $T^{HIVn,HIVp}$;
- They might die, the probability of which is described by DRT^{HIVn}; or
- They might survive and remain HIV negative at the start of year. The probability of this is described by $T^{HIVn,HIVn}$.

Since $T^{HIVn,HIVp}$, DRT^{HIVn} and $T^{HIVn,HIVn}$ exhaust the transition possibilities for an HIV-negative adult, (B.17) calculates $T^{HIVn,HIVn}$ as a residual of the two exogenous variables $T^{HIVn,HIVp}$ and DRT^{HIVn}.

Table 1. BOTE model: stylised representation of the main relationships in SAGE-H*

Equations holding within any given year of the year-on-year basecase and policy simulations	
$Y = C + I + \mathbf{G} + (X - M)$	(B.1)
$Y = \frac{1}{\mathbf{A}} \times f1(\mathbf{K}, LD)$	(B.2)
$C + \mathbf{G} = \mathbf{APC} \times GNP$	(B.3)
$\frac{\mathbf{G}}{C} = \grave{\imath}$	(B.4)
$GNP = \underset{+}{Y} \times f2\left(\underset{+}{TOT}\right) - \mathbf{FDATT} * \mathbf{R}$	(B.5)
$M = f3\left(\underset{+}{Y}, \underset{+}{TOT}, \underset{+}{\mathbf{Twist}^{pref}}\right)$	(B.6)
$TOT = \frac{PX}{\mathbf{PM}}$	(B.7)
$PX = f4\left(\underset{-}{X}, \underset{+}{\mathbf{F}^{d}}\right)$	(B.8)
$I = f5\left(\frac{ROR}{\underset{+}{\mathbf{F}^{inv}}}\right)$	(B.9)
$\Psi = \frac{I}{\mathbf{K}}$	(B.10)
$\left(\frac{\mathbf{K}}{LD}\right) = f6\left(\underset{-}{ROR}, \underset{+}{\mathbf{A}}, \underset{+}{TOT}, \underset{-}{\mathbf{Twist}^{lk}}\right)$	(B.11)
$\mathbf{W} = f7\left(\underset{+}{\frac{\mathbf{K}}{LD}}, \underset{+}{\mathbf{A}}, \underset{+}{TOT}, \underset{+}{\mathbf{Twist}^{lk}}\right)$	(B.12)
$LD = LS$	(B.13)
$LS = \mathbf{LS}^{\mathbf{HIVn}} \times ER^{HIVn} + \mathbf{LS}^{\mathbf{HIVp}} \times ER^{HIVp}$	(B.14)
$ER^{HIVn} = \mathbf{FER}^{\mathbf{HIVn}} \times FER$	(B.15)
$ER^{HIVp} = \mathbf{FER}^{\mathbf{HIVp}} \times FER$	(B.16)
Equations determining start-of-the-year variables in year-on-year basecase and policy simulations	
$T^{HIVn,HIVn} = \left(1 - \mathbf{T}^{\mathbf{HIVn,HIVp}} - \mathbf{DRT}^{\mathbf{HIVn}}\right)$	(B.17)
$LS^{HIVn} = \mathbf{LS}_{\mathbf{t-1}}^{\mathbf{HIVn}} \times T^{HIVn,HIVn} + \mathbf{NEWY}^{\mathbf{HIVn}}$	(B.18)
$LS^{HIVp} = \mathbf{LS}_{\mathbf{t-1}}^{\mathbf{HIVp}}\left(\mathbf{1} - \mathbf{DRT}^{\mathbf{HIVp}}\right) + HIV^{new} + \mathbf{NEWY}^{\mathbf{HIVp}}$	(B.19)
$HIV^{new} = \mathbf{LS}_{\mathbf{t-1}}^{\mathbf{HIVn}} \times \mathbf{T}^{\mathbf{HIVn,HIVp}}$	(B.20)
$K = \mathbf{K}_{\mathbf{t-1}}(1 - \mathbf{Depr}) + \mathbf{I}_{\mathbf{t-1}}$	(B.21)
$FDATT = \mathbf{FDATT}_{\mathbf{t-1}} + \mathbf{I}_{\mathbf{t-1}} - (1 - \mathbf{APC}_{\mathbf{t-1}})\,\mathbf{GNP}_{\mathbf{t-1}}$	(B.22)

* Variables in bold are exogenous. Remaining variables are endogenous.

Table 2. Description of variables used in the BOTE model

A	primary-factor augmenting technical change
APC , APC_{t-1}	average propensity to consume, years t and $t-1$
C	real private consumption
$Depr$	depreciation rate
DRT^{HIVn}	death rate of HIV-negative adults
DRT^{HIVp}	death rate of HIV-positive adults
ER^{HIVn}	employment rate for all HIV-negative adults
ER^{HIVp}	employment rate for all HIV-positive adults
$FDATT$	real net foreign liabilities in the current year
$FDATT_{t-1}$	real net foreign liabilities in year $t-1$
FER^{HIVn}	HIV-negative employment rate shift variable
FER^{HIVp}	HIV-positive employment rate shift variable
FER	General employment rate shift variable
F^{d}	export demand shift variable
F^{inv}	shift variable for investment
G	real government consumption
GNP , GNP_{t-1}	real (consumption price deflated) gross national product, years t and $t-1$
HIV^{new}	new HIV infections at the start of year t
I, I_{t-1}	real investment expenditure, years t and $t-1$ respectively
K , K_{t-1}	capital stock, years t and $t-1$ respectively
LD	labour demand
LS	labour supply
LS_{t-1}^{HIVn}	number of HIV-negative people in the labour force in year $t-1$
LS_{t-1}^{HIVp}	number of HIV-positive people in the labour force in year $t-1$
LS^{HIVn}	number of HIV-negative people in the labour force at the start of year t
LS^{HIVp}	number of HIV-positive people in the labour force at the start of year t
M	import volumes
$NEWY^{HIVn}$	HIV-negative new entrants to the labour force
$NEWY^{HIVp}$	HIV-positive new entrants to the labour force
PX, PM	foreign-currency export price, foreign-currency import price
R	interest rate on foreign liabilities
ROR	rate of return on capital
$T^{HIVn,HIVn}$	survival probability of an HIV-negative adult
$T^{HIVn,HIVp}$	probability of a person surviving to the next year and changing their HIV status from HIV negative to HIV positive

TOT	terms of trade
$Twist^{lk}$	capital-labour twist
$Twist^{pref}$	import-domestic twist
W	real (CPI-deflated) wage
X	export volumes
Y	real gross domestic product (GDP)
Γ	ratio of public to private consumption
Ψ	investment/capital ratio

Equation (B.18) relates the start-of-year number of HIV-negative adults in the labour force (LS^{HIVn}) to the number of HIV-negative adults in the labour force in year $t-1$ who survive to year t and remain HIV negative ($LS_{t-1}^{HIVn} \times T^{HIVn,HIVn}$) and the number of HIV-negative new entrants to the labour force (NEW^{HIVn}). Equation (B.19) relates the start-of-year number of HIV-positive people in the labour force (LS^{HIVp}) to the number of adults who were HIV positive in year $t-1$ and survive to year t ($LS_{t-1}^{HIVp} \times (1-DRT^{HIVp})$)[2], the number of new HIV infections (HIV^{new}) and the number of HIV-positive new entrants to the labour force (NEW^{HIVp}). Equation (B.20) defines the start-of-year number of new HIV infections (HIV^{new}) as the product of the number of HIV-negative adults during year $t-1$ (LS_{t-1}^{HIVn}) and the probability of changing HIV status from HIV negative to HIV positive ($T^{HIVn,HIVp}$).[3]

Equation (B.21) relates the start-of-year capital stock (K) to investment in the previous year (I_{t-1}) and depreciation on the existing capital stock. Equation (B.22) relates start-of-year foreign debt ($FDATT$) to the previous year's foreign debt ($FDATT_{t-1}$) and the excess of investments over savings.[4]

[2] Note that the survival probability in (B.19) refers to the probability of an HIV-positive person in year $t-1$ surviving to year t and still remaining part of the labour force ($1-DRT^{HIVp}$). In my labour-market framework, we restrict the activities HIV-positive people perform during the year. We assume that only those with an HIV stage of 1, 2 or 3 are part of the labour force. People in Stage 4 are too ill to be part of the labour force, and instead form part of the "permanently departed from the labour force" (PDL) activity. Therefore, in the BOTE model, the survival probability of an HIV person, still part of the labour force, refers to those with an HIV stage of Stages 1, 2 or 3.

[3] Note that the transition matrix in BOTE Equations (B.20) refers to the probability of a person moving from HIV negative to HIV positive ($T^{HIVn,HIVp}$). In the description of the full SAGE-H labour-market theory, this description specifically refers to the transition from HIV negative to Stage 1.

[4] The start-of-the-year foreign debt can be written as $FDATT = FDATT_{t-1} + CADEF_{t-1}$. This equation relates start-of-the-year foreign debt to the previous year's foreign debt and the current account deficit. The current account deficit is defined as $X - M$. We know that $X - M = I - S$. From the BOTE model, (B.3) implies that national savings are given as $(1-APC) \times GNP$. Hence, $CADEF = I - (1-APC) \times GNP$. Substituting $CADEF$ into $FDATT$ yields $FDATT = FDATT_{t-1} + I_{t-1} - (1-APC) \times GNP_{t-1}$.

2.1. Standard short-run closure

To complete the description of the BOTE model we have to consider an appropriate closure for Equations (B.1) to (B.22). I begin by noting that start-of-year values for $T^{HIVn,HIVn}$, LS^{HIVn}, LS^{HIVp}, HIV^{new}, K and $FDATT$ are uniquely determined by (B.17) to (B.22). As such, $T^{HIVn,HIVn}$, LS^{HIVn}, LS^{HIVp}, LS, HIV^{new}, K and $FDATT$, while formally endogenous, are effectively exogenous within any given year of a year-on-year simulation. Thus, recognising that equations (B.17) to (B.22) govern dynamics across years, our task of understanding the model closure narrows to choosing appropriate short-run closure for Equations (B.1) to (B.16).

Equations (B.1) to (B.16) comprise 16 equations and 32 unknowns. A conventional standard short-run closure of (B.1) to (B.16) would have X, Y, C, Γ, GNP, M, TOT, PX, I, Ψ, ROR, LD, LS, ER^{HIVn}, ER^{HIVn} and FER determined endogenously, given exogenous values for G, A, APC, $FDATT$, R, $Twist^{pref}$, PM, F^{d}, F^{inv}, $Twist^{lk}$, K W, LS^{HIVn}, LS^{HIVp}, FER^{HIVn} and FER^{HIVp}. Under this closure each equation can be associated with the determination of a specific endogenous variable.

With relatively high export demand elasticities and exogenous import prices, there is little scope for significant movements in the TOT. A convenient starting point then is to note that with little change in the TOT, and with A, W, $Twist^{lk}$ and K exogenous, (B.12) can be identified with the determination of LD. With W exogenous and (B.12) determining LD, (B.13) determines LS. With (B.13) determining LS, the HIV status-specific employment rates are determined by (B.14) to (B.16) via shifts in the uniform employment rate scalar FER. This reflects the assumption in SAGE-H of short-run stickiness in the real wage.

With A and K exogenous and LD determined by (B.12), (B.2) determines Y. With Y thus determined, Equations (B.3)–(B.5) determine GNP and its distribution between households and government. With GNP determined by (B.5) and APC and G exogenous, Equation (B.3) determines real private consumption, leaving (B.4) to determine Γ, the ratio of private to public consumption.

Again, ignoring for the moment the possibility of movements in the TOT, with Y determined by (B.2) and $Twist^{pref}$ exogenous, Equation (B.6) determines M. With LD determined by (B.12), and $Twist^{lk}$, K and A exogenous, (B.11) determines the rate of return on capital, ROR. This allows real investment (I) to be determined via (B.9). With I determined, (B.10) calculates Ψ. With Y, C, I, G and M explained, (B.1) determines X.

With *X* thus determined, the value of *PX* is determined by (B.8). With PM exogenous, and PX determined by (B.8), the TOT are determined by (B.7). The short-run closure described above is the starting point in developing the appropriate baseline forecast closure.

3. BASELINE FORECAST CLOSURE SETTINGS

3.1. Introduction

I develop three baseline closures for the baseline simulation. The choice of closures reflects the availability of actual or independent forecast data over our simulation period. Details of the three closures are summarised in Tables 3 and 4. In developing forecast closures I ensure that:

- dynamic year-on-year equations are activated. These equations track the change of variables, such as labour supply, capital stock and foreign debt through time;[5] and
- variables for which observed or independent data are available must be exogenised so that they can be shocked with the observed changes. The corresponding structural variables must be endogenised.

Table 3. Summary of the closures developed in generating a baseline forecast (2002–2045)

	Type	**Year**	**Type of data**
Baseline forecast	Forecast closure 1 (FC1)	2003–2009	Observed data
	Forecast closure 2 (FC2)	2010–2014	Independent forecast data
	Forecast closure 3 (FC3)	2015–2045	Assumes constant trend growth rates in selected macro variables

Table 4 lists the combination of endogenous and exogenous variables for the standard short-run closure (column 2) and the three forecast closures (columns 3–5) developed in this paper. I only include variables that appear in the BOTE model that are affected by swap statements. These variables are listed in column 1. Endogenous variables are indicated by “N” and exogenous variable by “X”. The endogenous/exogenous status of the BOTE variables for the standard short-run closure is listed in column 2. Since I have data available for many of the naturally endogenous variables listed in column 2, I move them to

[5] Recall that in the short-term closure these variables were exogenous. In the forecast closure, they are endogenous and determined via Equations (B.15) to (B.20). While these variables are formally endogenous, they can be thought of as effectively exogenous in any given year of a year-on-year simulation because they are determined by exogenous variables.

the exogenous list in the appropriate forecast closures. The final three columns in Table 4 list the endogenous/exogenous variables in each of the three forecast closures described and documented in Sections 3.2 and 3.3.

Table 4. Exogenous and endogenous variables in each forecast closure

	(1) Variables*	(2) Standard closure	(3) FC1 2003–2009	(4) FC2 2010–2014	(5) FC3 2015–2045
1	C	N	X	X	N
2	APC	X	N	N	X
3	I	N	X	X	N
4	F^{inv}	X	N	N	X
5	G	X	X	X	N
6	T	N	N	N	X
7	X	N	X	X	N
8	Y	N	N	N	X
9	A	X	N	N	N
10	M	N	X	X	N
11	$Twist^{pref}$	X	N	N	X
12	LD	N	X	X	X
13	$Twist^{lk}$	X	N	N	N
14	TOT	N	X	X	X
15	F^{d}	X	N	N	N
16	HIV^{new}	N	X	N	N
17	$T^{HIVn,HIVp}$	X	N	X	X

* Selected variables from the standard year-on-year dynamic closure represented in the BOTE model.
X = exogenous variables
N = endogenous variables

Table 5 summarises the swap statements used to change the endogenous/exogenous setting of selected variables applicable in the different forecast simulations. For example, aggregate employment (LD) is endogenous in the short-run closure (Table 4, row 12 column 2). However, I do have forecast data available for aggregate LD. To render LD exogenous, I endogenise $Twist^{lk}$ via a swap statement (Table 5, row 1). The endogenous/exogenous setting of LD and $Twist^{lk}$ after the swap statement is introduced is presented in Table 4, rows 12 and 13, columns 3 to 5. The last three columns in Table 5 indicate the forecasts in which these swap statements are introduced. These swap statements are explained in the relevant sections in this paper.

Table 5. Summary of swap statements used to alter the endogenous/exogenous status of selected variables

	New endogenous	*New exogenous*	*FC1*	*FC2*	*FC3*
1	labour/capital preference variable ($Twist^{lk}$)	aggregate employment (LD)	√	√	√
2	average propensity to consume (APC)	aggregate household consumption (C)	√	√	-
3	uniform investment shift variable (F^{inv})	aggregate investment (I)	√	√	-
4	import/domestic preference variable ($Twist^{pref}$)	aggregate imports (M)	√	√	-
5	uniform export shift variable (F^{d})	terms of trade (TOT)	√	√	√
6	technical change (A)	aggregate exports (X)	√	√	-
7	probability of a person surviving to the next year and changing their HIV status from negative to positive ($T^{HIVn,HIVp}$)	new HIV cases (HIV^{new})	√	-	-
8	aggregate public expenditure (G)	ratio of G to C (Γ)	-	-	√
9	technical change (A)	gross domestic product (Y)	-	-	√

3.2. Closure settings and shocks for the period 2003–2014

For the period 2003–2014 two forecast closures are developed, FC1 and FC2. In describing FC1 and FC2, I focus on four areas. First, I describe the data that are imposed on SAGE-H during this period. Based on the available forecast data, I then create the appropriate forecast closures. The second area of interest is on the closures for FC1 and FC2. These closures are described with the aid of the BOTE model where I clearly identify the exogenous and endogenous variables in FC1 and FC2. The BOTE model for FC1 is presented in Table 10 and for FC2 in Table 11. To create these closures, several swap statements are introduced to convert naturally endogenous variables, for which observed or independent data are available, and render them exogenous. Therefore, the focus of the third area is on the swap statements. The final area of interest focuses on the interpretation of the closures.

The descriptions of FC1 and FC2 are very similar in terms of my choice of endogenous and exogenous variables. For example, in both these forecast closures I exogenise C , I , M , LD

TOT and X and endogenise APC, F^{inv}, $Twist^{pref}$, $Twist^{lk}$, F^{d} and A.

There are two main differences between FC1 and FC2. The first difference is regarding the data. In FC1, I impose observed data for the main macroeconomic variables, that is, I exogenise variables for which observed data is available. In FC2, I exogenise variables for which independent forecast data are available. The second difference is regarding the closure itself. In FC1 we accommodate changes in the number of new HIV cases and allow SAGE-H to determine the transition rate from HIV negative to HIV positive. I do not accommodate any HIV data in FC2 and FC3.

3.2.1. Forecast data for 2003–2014

3.2.1.1. Observed data for South Africa: 2003–2009

From 2003 to 2009 I impose observed data on selected macroeconomic variables and the number of new HIV infections. The annual percentage change in these variables is summarised in Tables 6 and 7.

Table 6 summarises the annual percentage change in the data imposed on macroeconomic variables. Data for the GDP expenditure components are available from the South African Reserve Bank (SARB).

Table 6. Percentage change in real GDP expenditure components (2003–2009)

Variable	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
Real private consumption	3.5	6.7	6.9	8.3	6.6	2.3	-3.10
Real gross fixed capital formation	9.1	8.9	10.2	13.2	16.3	10.2	4.80
Real public consumption	6.3	6.2	4.8	5.1	4.8	5.0	4.00
Real exports	0.1	2.9	8.0	6.0	7.5	1.7	-17.7
Real imports	8.1	14.5	10.3	18.9	10.0	2.2	-11.5

Source: South African Reserve Bank.

Table 7 summarises the annual percentage change in the CPI, aggregate employment, real wage and new entrants. Data for the CPI are available from the SARB. The annual percentage change in aggregate employment is based on data published in various Labour Force Surveys (Statistics South Africa, 2008a, 2009a, 2009b, 2010a, 2010b). The percentage change in new entrants is based on population estimates from the International Labour Organisation (ILO).

My judgement on the growth in real wage is based on research by Altman (2005), Burger and Yu (2007) and Hlekiso and Mahlo (2006). Burger and Yu (2007) find that real wage earning increased in the post-apartheid period especially for formal sector employees. They find no evidence that wage earning decreased in the informal sector. In their CGE study of the impact of HIV on the South African economy, Arndt and Lewis (2000) assume a 2 per cent annual growth rate in real wage for unskilled labour (Arndt & Lewis, 2000: 13).

Table 7. Percentage changes in the CPI, employment, real wage and new entrants (2003–2009)

Variable	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
% change in CPI*	5.90	1.40	3.40	4.60	7.10	11.50	7.10
Employment [Ω]	1.13	1.92	5.65	4.06	3.95	3.06	-3.62
Real wage [ϒ]	2.0	2.0	2.0	2.0	2.0	2.0	2.0
New entrants [ϑ]	0.86	0.72	0.63	0.57	0.52	0.47	0.44

Source: * South African Reserve Bank.
ϑ International Labour Organisation, 2008.
Ω Labour Force Surveys, 2010a, 2010b, 2009a, 2009b, 2008a.
ϒ Based on Burger and Yu, 2007; Arndt and Lewis, 2000.

Forecasting the projected path the HIV epidemic will take in future is very difficult due to the uncertainty associated with the epidemic. Interpreting the results for prevalence rates is becoming more difficult because as the epidemic matures, prevention and treatment programs are implemented at the same time. Hence, it is difficult to determine whether the change in the epidemic is due to prevention and treatment or just the natural progression of the disease as it matures. Therefore, I only project the change in the number of new HIV infections for the period 2003–2008. I decided to forecast the number of new HIV infections for two reasons: (1) the number of new HIV cases reflects the underlying transmission dynamics currently at work in South Africa; (2) the spread and change of the HIV epidemic in South Africa are best tracked through measuring the number of new HIV cases. The number of new HIV cases is the key indicator of the rate of transmission and provides a means of assessing the impact of HIV prevention programs (Rehle *et al.*, 2007; 2010).

I base the HIV forecast of the number of new HIV infections on the study by Rehle *et al.* (2010). They analyse data from three national HIV household surveys conducted in 2002, 2005 and 2008. They find, for the period 2002–2005, that the incidence rate for men and women aged 15–49 is 2 per cent. The incidence rates are much higher for women at 2.8 per cent than men at 1 per cent. Also, the incidence rate is 10 times higher for young women aged 15–24 than men of the same age (Rehle *et al.*, 2010: 4).

For the period 2005–2008 they find that the overall incidence rate is 1.3 per cent for men and women aged 15–49. Overall, among adults the incidence rate declined by 35 per cent between the two survey periods. This decline was mostly due to change in the incidence rate among young women aged 15–24 (Rehle *et al.*, 2010: 4).

In terms of SAGE-H, the research by Rehle *et al.* (2010) can be viewed as a decrease in the number of new HIV infections by age, gender and race. To calculate the decline in the number of new HIV infections rate I assume that there is a decrease in the overall incidence rate of 35 per cent from the base year level. In FC1 I assume that: (1) the incidence rate for females aged 15–24 falls by 10 per cent per year; (2) for males in the same age group, new HIV infections fall by 6 per cent per year; and (3) for all other age groups the decline in new HIV infections is set at 2 per cent per year. For the period 2009–2045 I do not impose any HIV data.

3.2.1.2. Independent forecast data for South Africa: 2010–2014

For the period 2010–2014, I impose independent forecast data for selected macroeconomic variables. The percentage changes in these variables are summarised in Tables 8 and 9.

Table 8. Projected growth rates in real GDP expenditure components (2010–2014)

Variable	*2010*	*2011*	*2012*	*2013*	*2014*
Real private consumption	1.7	3.2	3.7	4.6	4.6
Real gross fixed capital formation	0.5	4.9	7.9	7.6	7.7
Real public consumption	4.2	4.3	4.4	4.5	4.5
Real exports	0.7	4.2	5.4	5.4	6.1
Real imports	8.8	6.0	7.0	8.2	8.5

Source: Industrial Development Corporation.

The forecast for the *GDP* expenditure components and *CPI* is adopted from the Industrial Development Corporation (IDC)[6] macroeconomic forecast. The annual percentage change in the employment level and new entrants to the labour force is based on ILO projections of the economically active population. The projection on the growth in real wage in FC2 is similar to that in FC1.

Table 9. Projected growth rates in the CPI, employment, real wage and new entrants (2010–2014)

Variable	*2010*	*2011*	*2012*	*2013*	*2014*
% change in CPI*	6.2	6.1	5.8	5.6	5.6
Employment $^{\Psi}$	0.42	0.45	0.48	0.52	0.55
Real wage $^{\Upsilon}$	2.0	2.0	2.0	2.0	2.0
New entrants $^{\Psi}$	0.43	0.44	0.45	0.46	0.45

Source: * Industrial Development Corporation.
Ψ International Labour Organisation, 2008.
Υ Based on Burger and Yu, 2007; Arndt and Lewis, 2000.

[6] The Industrial Development Corporation of South Africa Ltd (IDC) is a self-financing, national Development Finance Institution (DFI). It was established in 1940 to promote economic growth and industrial development in South Africa. With the aid of a macroeconometric model they produce forecasts of the South African economy.

3.2.2. The BOTE model describing FC1 and FC2

In this section I describe, with the aid of the BOTE model, the different closures developed for FC1 and FC2. The BOTE models depicting FC1 and FC2 are presented in Tables 10 and 11. The swap statements introduced to the short-run closure that enables me to create these closures are described in Section 5.1.3.

I create forecast closures for Equations (B.1) to (B.22). To understand the year-on-year dynamic closure, I begin by explaining Equations (B.17) to (B.22). These equations link the sequence of year-on-year comparative static simulations that constitute my dynamic equations. These equations form a useful, natural starting point for understanding (B.1) to (B.16).

In the standard short-run closure, labour supply distinguished by HIV status, capital and foreign debt are exogenous. These variables appear in (B.2), (B.5), (B.10) to (B.12) and (B.14). However, in a dynamic year-on-year closure these variables are determined by Equations (B.17) to (B.22) in the BOTE model. Notice that all the RHS variables of (B.17) and (B.20) to (B.22) are exogenous in the BOTE system of equations. As such, $T^{HIVn,HIVn}$, LS^{HIVn}, LS^{HIVp}, HIV^{new}, K and $FDATT$, while formally endogenous, are effectively exogenous in any given year of a year-on-year simulation.

The closure for Equations (B.1) to (B.16), (B.18), (B.21) and (B.22) are similar in both FC1 and FC2. Hence, the interpretation of the above-mentioned equations is similar in both FC1 and FC2. For these 19 equations we would have Y, A, APC, Γ, GNP, $Twist^{pref}$, PX, F^{d}, F_i^{inv}, Ψ, ROR, $Twist^{lk}$, ER^{HIVn}, ER^{HIVp}, FER, LS^{HIVn}, LS, K and $FDATT$ determined endogenously, given exogenous values for G, X, C, I, M, R, PM, TOT, LD, W, LS_{t-1}^{HIVn}, $NEWY^{HIVn}$, K_{t-1}, $Depr$, I_{t-1}, $FDATT_{t-1}$, APC_{t-1} and GNP_{t-1}. When I impose observed or independent forecast values for C, I, G, X, M, LD and W the model calculates movements in APC, F_i^{inv}, Γ, A, $Twist^{pref}$, FER and $Twist^{lk}$.

The only difference between FC1 and FC2 in terms of the closure relates to (B.17), (B.19) and (B.20). In FC1 I impose observed data for the number of new HIV cases. We therefore exogenise HIV^{new} and endogenise $T^{HIVn,HIVp}$. Both these variables appear in (B.20) in *FC1.* With HIV^{new} set exogenously, (B.20) determines $T^{HIVn,HIVp}$. LS^{HIVp} is determined in (B.19) and tied down by exogenous variables on the RHS of the equation. With $T^{HIVn,HIVp}$ determined in (B.20), (B.17) determines APC_{t-1}.

Table 10. BOTE model describing FC1 (2003–2009)*

Equations holding within any given year of the year-on-year basecase and policy simulations	
$Y = \boldsymbol{C} + \boldsymbol{I} + \boldsymbol{G} + (\boldsymbol{X} - \boldsymbol{M})$	(B.1)
$Y = \frac{1}{A} \times f1(K, \boldsymbol{LD})$	(B.2)
$\boldsymbol{C} + \boldsymbol{G} = APC \times GNP$	(B.3)
$\frac{\boldsymbol{G}}{\boldsymbol{C}} = ì$	(B.4)
$GNP = \underset{+}{Y} \times f2\left(\underset{+}{\boldsymbol{TOT}}\right) - FDATT * \boldsymbol{R}$	(B.5)
$\boldsymbol{M} = f3\left(\underset{+}{Y}, \underset{+}{\boldsymbol{TOT}}, \underset{+}{Twist^{pref}}\right)$	(B.6)
$\boldsymbol{TOT} = \frac{PX}{\boldsymbol{PM}}$	(B.7)
$PX = f4\left(\underset{-}{\boldsymbol{X}}, \underset{+}{F^{d}}\right)$	(B.8)
$\boldsymbol{I} = f5\left(\frac{ROR}{F^{inv}}\right)$	(B.9)
$\Psi = \frac{\boldsymbol{I}}{K}$	(B.10)
$\left(\frac{K}{\boldsymbol{LD}}\right) = f6\left(\underset{-}{ROR}, \underset{+}{A}, \underset{+}{\boldsymbol{TOT}}, \underset{-}{Twist^{lk}}\right)$	(B.11)
$\boldsymbol{W} = f7\left(\underset{+}{\frac{K}{\boldsymbol{LD}}}, \underset{+}{A}, \underset{+}{\boldsymbol{TOT}}, \underset{+}{Twist^{lk}}\right)$	(B.12)
$\boldsymbol{LD} = LS$	(B.13)
$LS = LS^{HIVn} \times ER^{HIVn} + LS^{HIVp} \times ER^{HIVp}$	(B.14)
$ER^{HIVn} = \boldsymbol{FER^{HIVn}} \times FER$	(B.15)
$\frac{G}{C} = \Gamma$	(B.16)
Equations determining start-of-the-year variables in year-on-year basecase and policy simulations	
$T^{HIVn,HIVn} = \left(1 - T^{HIVn,HIVp} - \boldsymbol{DRT^{HIVn}}\right)$	(B.17)
$LS^{HIVn} = \boldsymbol{LS_{t-1}^{HIVn}} * T^{HIVn,HIVn} + \boldsymbol{NEWY^{HIVn}}$	(B.18)
$LS^{HIVp} = \boldsymbol{LS_{t-1}^{HIVp}}\left(1 - \boldsymbol{DRT^{HIVp}}\right) + \boldsymbol{HIV^{new}} + \boldsymbol{NEWY^{HIVp}}$	(B.19)
$\boldsymbol{HIV^{new}} = \boldsymbol{LS_{t-1}^{HIVn}} \times T^{HIVn,HIVp}$	(B.20)
$K = \boldsymbol{K_{t-1}}(1 - \boldsymbol{Depr}) + \boldsymbol{I_{t-1}}$	(B.21)
$FDATT = \boldsymbol{FDATT_{t-1}} + \boldsymbol{I_{t-1}} - (1 - \boldsymbol{APC}) \times \boldsymbol{GNP_{t-1}}$	(B.22)

* Variables in bold are exogenous in FC1. Remaining variables are endogenous.

Table 11. BOTE model describing FC2 (2010–2014)*

Equations holding within any given year of the year-on-year basecase and policy simulations	
$Y = \mathbf{C} + \mathbf{I} + \mathbf{G} + (\mathbf{X} - \mathbf{M})$	(B.1)
$Y = \frac{1}{A} \times f1(K, \mathbf{LD})$	(B.2)
$\mathbf{C} + \mathbf{G} = APC \times GNP$	(B.3)
$\frac{\mathbf{G}}{\mathbf{C}} = \text{Ì}$	(B.4)
$GNP = \underset{+}{Y} \times f2\left(\underset{+}{\mathbf{TOT}}\right) - FDATT * \mathbf{R}$	(B.5)
$\mathbf{M} = f3\left(\underset{+}{Y}, \underset{+}{\mathbf{TOT}}, \underset{+}{Twist^{pref}}\right)$	(B.6)
$\mathbf{TOT} = \frac{PX}{\mathbf{PM}}$	(B.7)
$PX = f4\left(\underset{-}{\mathbf{X}}, \underset{+}{F^{d}}\right)$	(B.8)
$\mathbf{I} = f5\left(\frac{ROR}{F^{inv}}\right)$	(B.9)
$\Psi = \frac{\mathbf{I}}{K}$	(B.10)
$\left(\frac{K}{\mathbf{LD}}\right) = f6\left(\underset{-}{ROR}, \underset{+}{A}, \underset{+}{\mathbf{TOT}}, \underset{-}{Twist^{lk}}\right)$	(B.11)
$\mathbf{W} = f7\left(\underset{+}{\frac{K}{\mathbf{LD}}}, \underset{+}{A}, \underset{+}{\mathbf{TOT}}, \underset{+}{Twist^{lk}}\right)$	(B.12)
$\mathbf{LD} = LS$	(B.13)
$LS = LS^{HIVn} \times ER^{HIVn} + LS^{HIVp} \times ER^{HIVp}$	(B.14)
$ER^{HIVn} = \mathbf{FER^{HIVn}} \times FER$	(B.15)
$\frac{G}{C} = \Gamma$	(B.16)
Equations determining start-of-the-year variables in year-on-year basecase and policy simulations	
$T^{HIVn,HIVn} = \left(1 - \mathbf{T^{HIVn,HIVp}} - \mathbf{DRT^{HIVn}}\right)$	(B.17)
$LS^{HIVn} = \mathbf{LS^{HIVn}_{t-1}} \times T^{HIVn,HIVn} + \mathbf{NEWY^{HIVn}}$	(B.18)
$LS^{HIVp} = \mathbf{LS^{HIVp}_{t-1}}\left(1 - \mathbf{DRT^{HIVp}}\right) + HIV^{new} + \mathbf{NEWY^{HIVp}}$	(B.19)
$HIV^{new} = \mathbf{LS^{HIVn}_{t-1}} \times \mathbf{T^{HIVn,HIVp}}$	(B.20)
$K = \mathbf{K_{t-1}}(1 - \mathbf{Depr}) + \mathbf{I_{t-1}}$	(B.21)
$FDATT = \mathbf{FDATT_{t-1}} + \mathbf{I_{t-1}} - (1 - \mathbf{APC_{t-1}}) \times \mathbf{GNP_{t-1}}$	(B.22)

* Variables in bold are exogenous in FC2. Remaining variables are endogenous.

In FC2 I do not impose forecast data on the number of new HIV cases. In FC2, $T^{HIVn,HIVp}$ is exogenous and HIV^{new} endogenous. With $T^{HIVn,HIVp}$ exogenous, (B.20) determines HIV^{new} and (B.19) determines LS^{HIVp}. APC_{t-1} is tied down in (B.17) by the exogenous variables on the RHS of this equation. This closure setting for (B.17), (B.19) and (B.20) in FC2 and FC3 is similar to the short-run closure setting presented in Table 1.

3.2.3. Swap statements to create FC1 and FC2

In the short-run closure presented in Table 4, many of the variables for which observed data are available are naturally endogenous. To accommodate observed changes in naturally endogenous variables, swap statements are introduced whereby naturally exogenous variables are endogenised and the naturally endogenous variables are exogenised. Stated differently, I introduce swap statements to the short-run closure, which enables me to create the closures described in the previous section. In Table 4 the combination of endogenous/exogenous variables for FC1 and FC2 are listed in columns 3 and 4.

In developing FC1 and FC2 I ensure that:

- dynamic year-on-year equations that track the change in stock variables are activated. This is applicable to both FC1 and FC2;
- economic variables for which observed or independent data are available, must be exogenised so that they can be shocked with the observed changes. The corresponding structural variables must be endogenised. This is applicable to both FC1 and FC2; and
- variables for which I have observed HIV data must be exogenised and the corresponding behavioural variables endogenised. This is only applicable in FC1.

3.2.3.1. Swap statements to activate year-on-year economic equations

The following discussion is relevant to both FC1 and FC2 and is applicable to Equations (B.14), (B.18), (B.19), (B.21) and (B.22) in Tables 10 and 11.

Forecast simulations are performed as a sequence of year-on-year solutions. Because the forecast simulation generates annual solutions, start-of-year stock variables for year t are completely determined by the end-of-year stock variables in year $t-1$. While the start-of-the-year stock variables can be thought of as exogenous at the start-of-the-year in the year t, they should be thought of as endogenous for the annual end-of–the-year solutions produced in a forecast simulation. In the BOTE model, start-of-the-year stock variables are determined via (B.21) and (B.22).

The mechanism that allows start-of-the-year stock variables to take the end-of-year value is activated via shocks to the *del_unity* variable. By shocking the *del_unity* variable with 1 during year t s simulation, I ensure that the start-of-the-year values for all stock variables are similar to the end-of-the-year values. The *del_unity* variable is naturally exogenous and therefore no swap statement is required.

In this dynamic framework I allow labour supply to change over time. Labour supply grows over time via positive shocks to new entrants to the labour supply distinguished by HIV status ($NEWY^{HIVn}$, $NEWY^{HIVp}$). These variables appear in (B.18) and (B.19) in the BOTE model. The new entrant variables are naturally exogenous in our BOTE model and therefore no swap statement is required. At the same time, the labour force shrinks because I allow people to leave the labour force through death or retirement. In the BOTE model, the outflow of people is facilitated via the initial setting of the death rates. Throughout the forecast simulation period I hold the death rates (DRT^{HIVn}, DRT^{HIVp}) constant at their 2002 levels. These variables appear in (B.17) and (B.19). During the forecast simulation I introduce positive shocks to APC and $NEWY^{HIVp}$ while holding DRT^{HIVn} and DRT^{HIVp} constant at their 2002 levels. The net impact is an increase in the labour supply over time.

3.2.3.2. Swap statements to introduce observed macroeconomic data

The following discussion is relevant to both FC1 and FC2. The choice of exogenous macroeconomic variables in FC1 and FC2 depends on the availability of data. In this thesis the GDP expenditure components, aggregate employment and the real wage rate are shocked with exogenously determined data. These variables are naturally endogenous in the standard short-run closure reported in Table 4, column 2. To render them exogenous, seven swap statements are introduced in both FC1 and FC2. These swap statements are reported in Table 12.

Swap statement (1) exogenises aggregate employment (LD) by endogenising the labour-capital twist variable ($Twist^{lk}$). Swap statement (2) exogenises aggregate private consumption (C) and endogenises the average propensity to consume (APC). In the short-run closure, aggregate government consumption (G) is already exogenous and the ratio of private to public consumption (Γ) endogenous. Hence, no swap statement is required to exogenise G.

Table 12. Swap statements to introduce macroeconomic data in FC1 and FC2*

	New endogenous	*New exogenous*
swap 1	labour/capital preference variable ($Twist^{lk}$)	aggregate employment (LD)
swap 2	average propensity to consume (APC)	aggregate household consumption (C)
swap 3	uniform investment shift variable (F^{inv})	aggregate investment (I)
swap 4	import/domestic preference variable ($Twist^{pref}$)	aggregate imports (M)
swap 5	uniform export shift variable (F^{d})	terms of trade (TOT)
swap 6	technical change (A)	aggregate exports (X)

* These swap statements apply to the variables included in our BOTE model.

Swap (3) exogenises aggregate investment and endogenises the investment shift variable. This swap allows SAGE-H to accommodate exogenously given movements in aggregate investment via a uniform shift in the rate-of-return/capital-growth relationship. Hence, I allow for a uniform vertical shift in the capital supply curve for each industry. Swap (4) exogenises aggregate import volumes (M) and endogenises the import/domestic preferences ($Twist^{pref}$). Swap (5) exogenises the terms of trade (TOT) and endogenises the uniform vertical shifter (F^{d}) on all export demand curves. This allows for the assumption that as the South African economy expands, foreign markets for South African commodities will be found so that there is no change in the terms of trade. This ensures that throughout our forecast simulation, foreign demand schedules for South African exports shift in a north-easterly direction, thereby accommodating expansions in exports at a given terms of trade.

The closure thus far renders C, I, G, M and LD exogenous. Therefore, with LD and A exogenous and K predetermined by I, Y is determined from the supply side via (B.2) in Tables 10 and 11. If X is exogenised, Y is also determined from the demand side via (B.1). If X is exogenised without endogenising a variable describing the supply side of the economy, *GDP* as determined via (B.1) will not equal *GDP* determined via (B.2). The appropriate swap (swap 6) is to exogenise aggregate exports (X) and to endogenise the overall primary-factor technology change (A) variable. This allows technical change to adjust to accommodate the change in exports.

3.2.3.3. Swap statement to accommodate HIV data in FC1

As mentioned before, I only accommodate data on the number of new HIV cases for the period 2003–2009 and not for 2010–2014. Hence, the description in this section only applies to FC1 and not FC2.

Recall from the discussion on Equation (B.20) in Section 2 that the number of new HIV cases (HIV^{new}) at the start of year t is determined by the number of HIV-negative people in the labour force during year $t-1$ (LS_{t-1}^{HIVn}) and a constant probability of surviving to the next year and changing HIV status from HIV negative to HIV positive ($T^{HIVn,HIVp}$). However, for the period 2003–2008, I have data available on the number of new HIV cases. To accommodate this data I introduce swap 7.

With swap 7 we exogenise the number of new HIV infections and endogenise the probability that an adult will change their HIV status from HIV negative to positive ($T^{HIVn,HIVp}$). This swap allows HIV^{new} to be shocked with observed data and $T^{HIVn,HIVp}$ to adjust to accommodate this shock.

Table 13. Swap statement to introduce HIV data in FC1

	New endogenous	***New exogenous***
Swap 7	probability of a person surviving to the next year and changing their HIV status from negative to positive ($T^{HIVn,HIVp}$)	new HIV cases (HIV^{new})

3.2.4. Interpretation of FC1 and FC2

As noted before, swap statements 1 to 6 are applicable to both FC1 and FC2 and as such the interpretation of these swaps will be similar. Swap statement 7 only applies to FC1 and therefore the interpretation of swap 7 only applies to FC1. I will clearly state in the text when the interpretation differs.

To interpret the closure it may be helpful to first consider the interpretation of Equations (B.13) to (B.20). Equations (B.18) and (B.19) determine year-on-year movements in labour supply, distinguished by labour force based on HIV status. Equation (B.14) determines start-of-the-year labour force, as the sum of HIV-negative workforce participants and HIV-positive workforce participants. Note that the interpretation of these equations in FC1 and FC2 are different.

In FC1, I exogenise the number of new HIV cases (HIV^{new}) and endogenise the probability of an adult surviving to the next year and changing health status from HIV negative to HIV positive ($T^{HIVn,HIVp}$). With LS_{t-1}^{HIVn} and HIV^{new} exogenous, (B.20) determines $T^{HIVn,HIVp}$. With DRT^{HIVn} exogenous and $T^{HIVn,HIVp}$ determined via (B.20), Equation (B.17) determines the survival probability of an HIV-negative adult (APC_{t-1}). With APC and LS_{t-1}^{HIVn} exogenous and APC_{t-1} determined via (B.17), (B.18) calculates the number of HIV-negative adults in the labour force (LS^{HIVn}). The HIV-positive labour force (LS^{HIVp}) is tied down by all the exogenous variables on the RHS of (B.19). With LS tied down in (B.13), (B.14) determines ER^{HIVn} and ER^{HIVp} via shifts in FER which appears in (B.15) and (B.16).

In FC2, I do not accommodate exogenous data on the number of new HIV cases. Hence, the closure for (B.19) and (B.20) in FC2 is similar to the short-run closure presented in Table 7.1. With LS_{t-1}^{HIVn} and $T^{HIVn,HIVp}$ exogenous, (B.20) determines HIV^{new} . With HIV^{new} determined and LS_{t-1}^{HIVp} , DRT^{HIVp} and $NEWY^{HIVp}$ exogenous, (B.19) determines LS^{HIVp} . The survival probability of an HIV-negative adult (APC_{t-1}) is tied down by the exogenous setting of DRT^{HIVn} and $T^{HIVn,HIVp}$ in (B.17). With LS_{t-1}^{HIVn} , APC_{t-1} and $NEWY^{HIVn}$ exogenous, the number of HIV-negative people in the labour force (LS^{HIVn}) is determined via (B.18). Again, with LS tied down in (B.13), (B.14) determines ER^{HIVn} and ER^{HIVp} via shifts in FER which appears in (B.15) and (B.16).

The following interpretation of the remaining equations is similar for both FC1 and FC2. With C , I , G , X and M exogenous, Y is determined via (B.1). With K tied down by I via (B.19), LD exogenous and Y determined via (B.1), Equation (B.2) determines A . With the TOT and R exogenous and $FDATT$ tied down in (B.20), (B.5) determines GNP . With GNP determined via (B.5) and C and G exogenous, (B.3) determines the APC . With M and TOT exogenous, and Y determined, (B.6) determines the change in consumer import/domestic preference ($Twist^{pref}$). With the price of exports tied down by the terms of trade in (B.7), (B.8) determines the shift in export demand (F^{d}) for South African commodities. With the TOT , W and LD exogenous, A determined via (B.2) and K predetermined by I , (B.12) determines the labour-capital twist ($Twist^{lk}$). This leaves (B.11) to determine ROR . With I exogenous, (B.9) determines the general shift variable (F^{inv}) and Ψ in (B.10).

3.3. Closure settings and shocks for 2015–2045

In this section I describe the closure settings for the final forecast closure (FC3), developed for years 2015–2045. No independent forecast data are available for this time period. Due to the lack of forecast data, my choice of which variable to forecast narrows to real GDP , aggregate employment, real wage and new entrants.

3.3.1. Data for South Africa: 2015–2045

No independent forecast data are available for this period. From 2015 I assume that *GDP* continues to grow at a constant rate of 4 per cent per year and real wages at 2 per cent per year. The annual percentage change in the employment level and new entrants to the labour force is summarised in Table 14. As with FC1 and FC2 these forecast values are based on the population projections by the ILO (2008). The ILO projections are only until 2020. Thereafter, I assume that employment grows at a constant rate of 0.76 per cent per year and new entrants into the labour force at a constant rate of 0.08 per cent per year.

Table 14. Forecast values for employment and population growth (2015–2045)

Variable	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021–2045*
Employment	0.59	0.63	0.68	0.72	0.75	0.76	0.76
New entrants	0.40	0.33	0.25	0.18	0.12	0.08	0.08

Source: International Labour Organisation, 2008.

3.3.2. The BOTE model describing FC3

As with FC1 and FC2, I have to consider an appropriate year-on-year closure for 2015 to 2045. Table 15 reflects the year-on-year closure developed for FC3 and Table 4, column 5 lists the combination of endogenous/exogenous variables relevant for FC3.

As with FC1 and FC2, FC3 includes 22 BOTE equations containing 47 variables. With each equation determining an endogenous variable, 25 exogenous variables are required. For the 22 equations, FC3 would have X, A, C, G, GNP, M, PX, F^d, I, Ψ, ROR, $Twist^{lk}$, LS, ER^{HIVn}, ER^{HIVp}, FER, $T^{HIVn,HIVn}$, LS^{HIVn}, LS^{HIVp}, HIV^{new}, K and $FDATT$ determined endogenously, given exogenous values for Y, APC, R, $Twist^{pref}$, Γ, PM, TOT, F_i^{inv}, W, LD, FER^{HIVn}, FER^{HIVp}, $T^{HIVn,HIVp}$, DRT^{HIVn}, LS_{t-1}^{HIVn}, $NEWY^{HIVn}$, LS_{t-1}^{HIVp}, DRT^{HIVp}, $NEWY^{HIVp}$, K_{t-1}, $Depr$, I_{t-1}, $FDATT_{t-1}$, APC_{t-1} and GNP_{t-1}.

3.3.3. Swap statements to create FC3

In developing FC3, I ensure that:

- the dynamic year-on-year equations are activated allowing the change in stock variables to be tracked through time; and
- I exogenise variables, which allows me to impose exogenously

determined values by endogenising relevant structural variables.

Similar to FC1 and FC2, no swap statements are introduced to activate the year-on-year equations. In FC3 I do not accommodate any HIV data, and therefore no swap statements are introduced. To accommodate shocks to selected macroeconomic variables, I introduce swap statements to transform the standard short-run closure, presented in Table 4, into FC3. The swap statements are presented in Table 15.

Swap statement (1) exogenises aggregate employment (LD) by endogenising the labour-capital twist variable ($Twist^{lk}$). Swap statement (2) exogenises the terms of trade (TOT) by endogenising the uniform shifter on all export demand curves (F^d).

Table 15. Swap statements to introduce macroeconomic data in FC3*

	New endogenous	*New exogenous*
swap 1	labour/capital preference variable ($Twist^{lk}$)	aggregate employment (LD)
swap 2	uniform export shift variable (F^d)	terms of trade (TOT)
swap 3	aggregate public expenditure (G)	ratio of G to C (Γ)
swap 4	technical change (A)	gross domestic product (Y)

* These swap statements apply to the variables included in our BOTE model.

Swap statement (3) exogenises the ratio of private to public consumption by endogenising aggregate public spending. By setting Γ exogenous I ensure that C and G follow the same path. The final swap statement exogenises gross domestic product (Y) by endogenising technical change (A).

Table 16. BOTE model describing FC3 (2015–2045)*

Equations holding within any given year of the year-on-year basecase and policy simulations	
$\boldsymbol{Y} = C + I + G + (X - M)$	(B.1)
$\boldsymbol{Y} = \frac{1}{A} \times f1(K, \boldsymbol{LD})$	(B.2)
$C + G = \boldsymbol{APC} \times GNP$	(B.3)
$\frac{G}{C} = \boldsymbol{\grave{I}}$	(B.4)
$GNP = \underset{+}{\boldsymbol{Y}} \times f2\left(\underset{+}{\boldsymbol{TOT}}\right) - FDATT * \boldsymbol{R}$	(B.5)
$M = f3\left(\underset{+}{\boldsymbol{Y}}, \underset{+}{\boldsymbol{TOT}}, \underset{+}{\boldsymbol{Twist}^{pref}}\right)$	(B.6)
$\boldsymbol{TOT} = \frac{PX}{\boldsymbol{PM}}$	(B.7)
$PX = f4\left(\underset{-}{X}, \underset{+}{F^{d}}\right)$	(B.8)
$I = f5\left(\frac{ROR}{\boldsymbol{F}^{\boldsymbol{inv}}}\right)$	(B.9)
$\Psi = \frac{I}{K}$	(B.10)
$\left(\frac{K}{\boldsymbol{LD}}\right) = f6\left(\underset{-}{ROR}, \underset{+}{A}, \underset{+}{\boldsymbol{TOT}}, \underset{-}{Twist^{lk}}\right)$	(B.11)
$\boldsymbol{W} = f7\left(\underset{+}{\frac{K}{\boldsymbol{LD}}}, \underset{+}{A}, \underset{+}{\boldsymbol{TOT}}, \underset{+}{Twist^{lk}}\right)$	(B.12)
$\boldsymbol{LD} = LS$	(B.13)
$LS = LS^{HIVn} \times ER^{HIVn} + LS^{HIVp} \times ER^{HIVp}$	(B.14)
$ER^{HIVn} = \boldsymbol{FER}^{\boldsymbol{HIVn}} \times FER$	(B.15)
$\frac{\boldsymbol{G}}{C} = \Gamma$	(B.16)
Equations determining start-of-the-year variables in year-on-year basecase and policy simulations	
$T^{HIVn,HIVn} = \left(1 - \boldsymbol{T}^{\boldsymbol{HIVn,HIVp}} - \boldsymbol{DRT}^{\boldsymbol{HIVn}}\right)$	(B.17)
$LS^{HIVn} = \boldsymbol{LS}_{\boldsymbol{t-1}}^{\boldsymbol{HIVn}} \times T^{HIVn,HIVn} + \boldsymbol{NEWY}^{\boldsymbol{HIVn}}$	(B.18)
$LS^{HIVp} = \boldsymbol{LS}_{\boldsymbol{t-1}}^{\boldsymbol{HIVp}}\left(1 - \boldsymbol{DRT}^{\boldsymbol{HIVp}}\right) + HIV^{new} + \boldsymbol{NEWY}^{\boldsymbol{HIVp}}$	(B.19)
$HIV^{new} = \boldsymbol{LS}_{\boldsymbol{t-1}}^{\boldsymbol{HIVn}} \times \boldsymbol{T}^{\boldsymbol{HIVn,HIVp}}$	(B.20)
$K = \boldsymbol{K}_{\boldsymbol{t-1}} \times (1 - \boldsymbol{Depr}) + \boldsymbol{I}_{\boldsymbol{t-1}}$	(B.21)
$FDATT = \boldsymbol{FDATT}_{\boldsymbol{t-1}} + \boldsymbol{I}_{\boldsymbol{t-1}} - (1 - \boldsymbol{APC}_{\boldsymbol{t-1}}) \times \boldsymbol{GNP}_{\boldsymbol{t-1}}$	(B.22)

* Variables in bold are exogenous in FC3. Remaining variables are endogenous.

3.3.4. Interpretation of FC3

To interpret FC3, it may be useful to first consider the interpretation of Equations (B.13) to (B.22). Recall that Equations (B.18) and (B.19) determine year-on-year movement in labour supply, distinguished by labour supply based on HIV status. Equation (B.14) determines the start-of-the-year labour supply summed across HIV status of the workforce. With the number of HIV-negative adults in the labour force during year $t-1$ (LS_{t-1}^{HIVn}) and the probability of a person becoming HIV positive ($T^{HIVn,HIVp}$) set exogenous, Equation (B.20) determines the number of new HIV cases (HIV^{new}) at the start of the year. With HIV^{new} determined via (B.20) and the number of HIV-positive adults in the labour force (LS_{t-1}^{HIVp}), the survival probability of an HIV-positive adult ($T^{HIVp,HIVp}$) and the number of HIV-positive new entrants into the labour force ($NEWY^{HIVp}$) set exogenous, (B.19) determines the total number of HIV-positive adults in the labour force at the start of the year (LS^{HIVp}). Similarly, with the number of HIV-negative adults in the labour force (LS_{t-1}^{HIVn}), the survival probability of an HIV-negative adult ($T^{HIVn,HIVn}$) and HIV-negative new entrants into the labour force (APC) set exogenously, the total number of HIV-negative adults in the labour force at the start of the year (LS^{HIVn}) is determined via (B.18). With LS tied down in (B.13), (B.14) determines ER^{HIVn} and ER^{HIVp} via changes in FER.

As in FC1 and FC2, start-of-the-year capital stock and foreign debt are effectively exogenous in any year-on-year simulation because they are dependent on exogenous variables specified on the RHS of (B.21) and (B.22). Start-of-the-year capital stock is tied down by investment in year $t-1$ and depreciation on existing capital stock. Start-of-the-year foreign debt is dependent on existing foreign debt in year $t-1$ and the current account deficit in year $t-1$.

Our attention now shifts to the interpretation of (B.1) to (B.12). With GDP (Y) and aggregate employment (LD) exogenous and capital stock tied down in (B.21), Equation (B.2) determines technology (A). With the terms of trade and interest payments on foreign debt set exogenous, (B.5) determines GNP. Aggregate consumption ($C+G$) is linked to gross national product (GNP) via an exogenously set average propensity to consume (APC) in (B.3). With GDP the main determinant of GNP, we see that real aggregate consumption tracks GDP closely. With the ratio of private-public consumption (Γ) set exogenously in (B.4), we ensure that C and G follow the same path. Equation (B.6) shows that imports (M) follow GDP, given the exogenous setting of the terms of trade (TOT) and import/domestic twist ($Twist^{pref}$). With the terms of trade (TOT), real wage (W) and aggregate employment (LD) exogenous, capital stock (K) tied down via (B.21) and technology (A) determined via (B.2), (B.12) determines the labour-capital twist variable ($Twist^{lk}$). This leaves (B.11) to determine the rate of return (ROR), (B.9) to determine investment (I) and (B.10) to determine Ψ . With Y exogenous and C , I , G and M determined, Equation (B.1) determines exports (X). With X determined and the price of exports tied down in (B.7), (B.8) determines F^d .

This ends our description of the final forecast closure developed for the period 2015–2045. The three forecast closures together with the imposed data produce a baseline forecast path for the South African economy for the period 2003–2045. In the next section I review the forecast results produced by SAGE-H.

3.4. Results for the baseline forecast

Our discussion mainly focuses on all the macro variables in SAGE-H equivalent to those represented in our BOTE model. Given our description of the different closures, our discussion of the forecast results is divided into two broad discussions. The first discussion focuses on the results from 2003 to 2014 where all expenditure components of GDP as well as real wages (W), aggregate employment (LD) and new entrants to the labour force ($NEWY^{HIVn}, NEWY^{HIVp}$) are moved to the exogenous list and shocked. For 2003 to 2014, the appropriate closures are represented in Tables 10 and 11. From 2015 to 2045 I set real GDP as well as W , LD and the TOT exogenous and allow the expenditure components to be determined endogenously. The appropriate closure for this period is presented in Table 16. Notice that throughout the entire simulation period (2003–2045) LD , W , $NEWY^{HIVn}$ and $NEWY^{HIVp}$ are set at their forecast values.

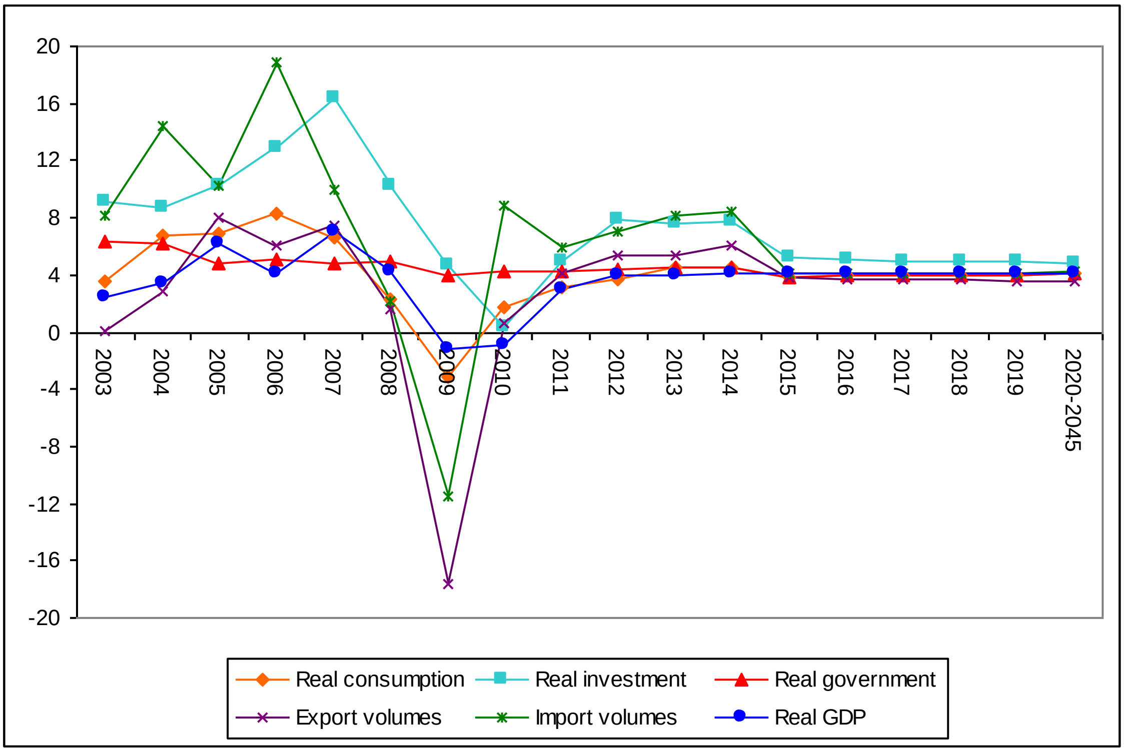
3.4.1. Expenditure components of GDP

Figure 1 reports year-on-year percentage change in real GDP as well as all the GDP expenditure components. For the period 2003–2014, the forecast paths of the expenditure components imply an annual average growth rate for real GDP of 3.3 per cent per annum. The reader will recall that our forecast data for this period is adapted from the SARB and the IDC. The IDC forecast stops in 2014. Thereafter, all the demand side components are returned to the endogenous category and forecast GDP. I assume that for the remainder of the forecast period, GDP continues to grow at 4 per cent per annum.

As already discussed, for 2003 to 2014, C , I , G , X and M are exogenous and shocked with exogenously determined data. Our data show that real investment grows faster than private and public consumption at an annual average growth rate of 8.3 per cent. Private and public spending grows at an average annual rate of 4.02 and 4.82 per cent respectively.

Our data further suggest large positive growth in imports particularly from 2003 to 2007. For the period 2003 to 2014 the annual average import growth rate is 7.3 per cent. The growth in imports reflects the change in consumers' tastes and industries' demand for commodities that tend to favour import-intensive commodities. In our BOTE model this preference towards imported commodities is reflected by the positive value in the import/domestic preference variable ($Twist^{pref}$). Exports grow at a lower rate than imports reflecting a trade deficit. For the period 2003–2014 the annual average export growth rate is 2.2 per cent. The export data imposed suggests a positive shift in F^d reflecting the growth in world trade and demand for South African produced commodities. Export volumes are particularly affected during the Global Financial Crisis with exports falling by 18 per cent in 2009.

Figure 1. GDP expenditure components, 2003–2045 (year-on-year percentage change)



The Global Financial Crisis is the main reason for the negative growth in all, except public spending, expenditure components. Figure 1 shows that private consumption and trade are most severely affected. *GDP* recovers and in the final two years of the forecast is projected to grow at approximately 4 per cent per annum.

From 2014 onwards, no independent forecast data are available for the *GDP* expenditure components. I therefore exogenise real *GDP* and return all the *GDP* expenditure components to the endogenous list. I assume that *GDP* grows at a constant rate of 4 per cent per annum. SAGE-H generates the change in the expenditure components consistent with our expectation regarding the annual percentage growth in real *GDP*.

As described in the BOTE model I expect imports to follow *GDP*. This is achieved via equation (B.6) by moving the terms of trade and the import/domestic preference variable to the exogenous list. The growth in public and private consumption is linked to the growth in gross national product (*GNP*) via an assumption of fixed propensity to consume (*APC*). In terms of Equation (B.3) in our BOTE model, *APC* is exogenous, ensuring that C and G move with *GNP*. Since *GDP* is the main determinant of *GNP*, I expect real consumption to track *GDP* closely. This is evident in Equation (B.5). The split between private and public consumption growth is determined by setting Γ exogenous, ensuring that G grows at the same rate as C. With *GDP* exogenous and with aggregate consumption and investment growth closely tracking *GDP* growth, the BOTE equation (B.1) suggests that export growth should closely follow import growth.

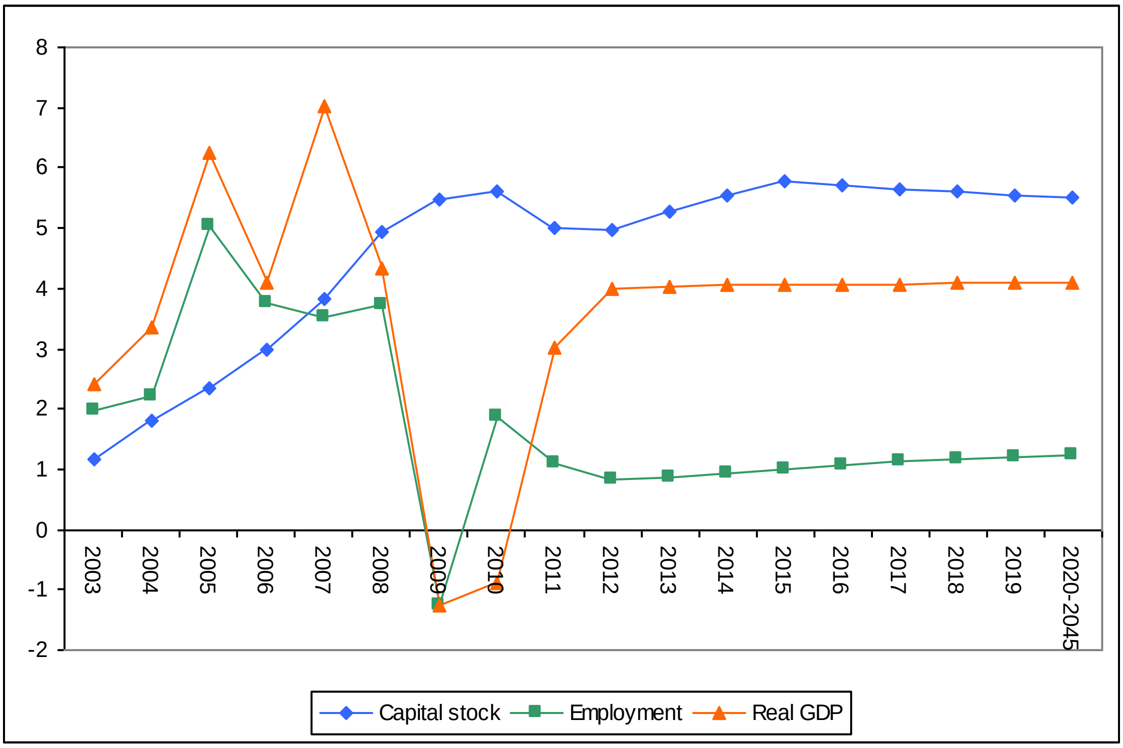
3.4.2. Supply-side components of GDP

We now turn our attention to how *GDP* is determined from the supply side. In the following discussion we need to remember the following: firstly, for the entire forecast period (2003–2045) the aggregate level of employment (LD) and the real wage (W) are set at exogenously determined values. Secondly, from 2003 to 2014, *GDP* is determined from the expenditure side via exogenously given values for C, I, G, X and M. During this period, K is determined by investment via (B.19) and A is endogenously determined to allow for our assumptions regarding X and the *TOT*. Thirdly, from 2015 to 2045, *GDP* is assumed to grow at a constant rate of 4 per cent.

For years 2003 to 2014, the appropriate closures are presented in Tables 10 and 11. In these closure settings, the growth in capital stock is effectively determined by the growth in aggregate investment via the capital accumulation mechanism captured via (B.19). The strong growth in investment (Figure 1) during this period accounts for the increase in capital stock. Our data suggest that, between 2003 and 2014, capital grows at an annual average rate of 4.1 per cent. The annual capital growth rate increases steadily over the period, beginning at 1.15 per cent in 2003 and increasing to 5.5 per cent by 2014.

With *GDP* determined via (B.1), capital stock determined by aggregate investment and the growth in aggregate employment set at exogenously imposed values, the implied average growth rate in productivity is 0.4 per cent per annum. The year-on-year percentage change in employment, capital and *GDP* is plotted in Figure 2.

Figure 2. Supply-side GDP components, 2003–2045 (year-on-year percentage change)



For years 2003 to 2009, observed employment data are taken from the LFS (2009a, 2009b, 2010a, 2010b). The data shows that, apart from 2009, employment growth is positive over this period. The impact of the financial crisis is reflected in 2009, when employment falls by 3.62 per cent. The observed data imply an annual average employment growth rate of 2.2 per cent.

From 2010 to 2020, our employment growth is based on ILO projections of the economically active population. For this period, ILO projects an annual average rate of growth in the economically active population of 0.6 per cent. The annual growth rate increases steadily over the period, beginning at 0.42 per cent in 2010, increasing to 0.76 per cent by 2020. From 2020 to 2045 I assume that employment grows at a constant rate of 0.76 per annum. Our results further show that given the growth rates in employment and capital in the baseline scenario, the economy is more capital-intensive, reflecting the slower growth in labour and the increase in real wages.

3.4.3. Labour-market specific projections

We now turn our attention to labour-market specific projections. We specifically consider the percentage change in the number of employed and unemployed adults. Recall that the labour force[7] expands via the growth in new entrants to the labour force. This is a positive shock to new entrants that allows the labour force to grow over time. In our BOTE model, new entrants to the labour force appear in Equations (B.17) and (B.18). I also allow the labour force to contract as people leave the labour force through death or retirement via our initial setting of the transition matrix.[8] In the BOTE model, the transition matrices capturing the survival probability by HIV status appear in Equations (B.17), (B.18), (B.19) and (B.20). Overall the percentage change in the labour force is dependent on our setting of the growth in new entrants and those leaving the labour force through death and retirement.

For the period 2002–2020, ILO projects an annual average rate of growth in the new entrants of 0.43 per cent. However, the annual growth rate declines steadily over the period, beginning at 0.86 per cent in 2003, and falling to 0.08 per cent by 2020. From 2020 to 2045 I assume that new entrants into the labour force grow at a constant rate of 0.08 per annum. The number of employed people is based on LFS and ILO data. For the period 2002–2020 the annual average rate of growth in employed persons is 1.2 per cent. However, the annual growth rate declines steadily over the period, beginning at 1.13 per cent in 2003, increasing to 5.65 per cent in 2005 and falling to 0.76 per cent by 2020. From 2020 to 2045 I assume that employment grows at a constant rate of 0.76 per annum.

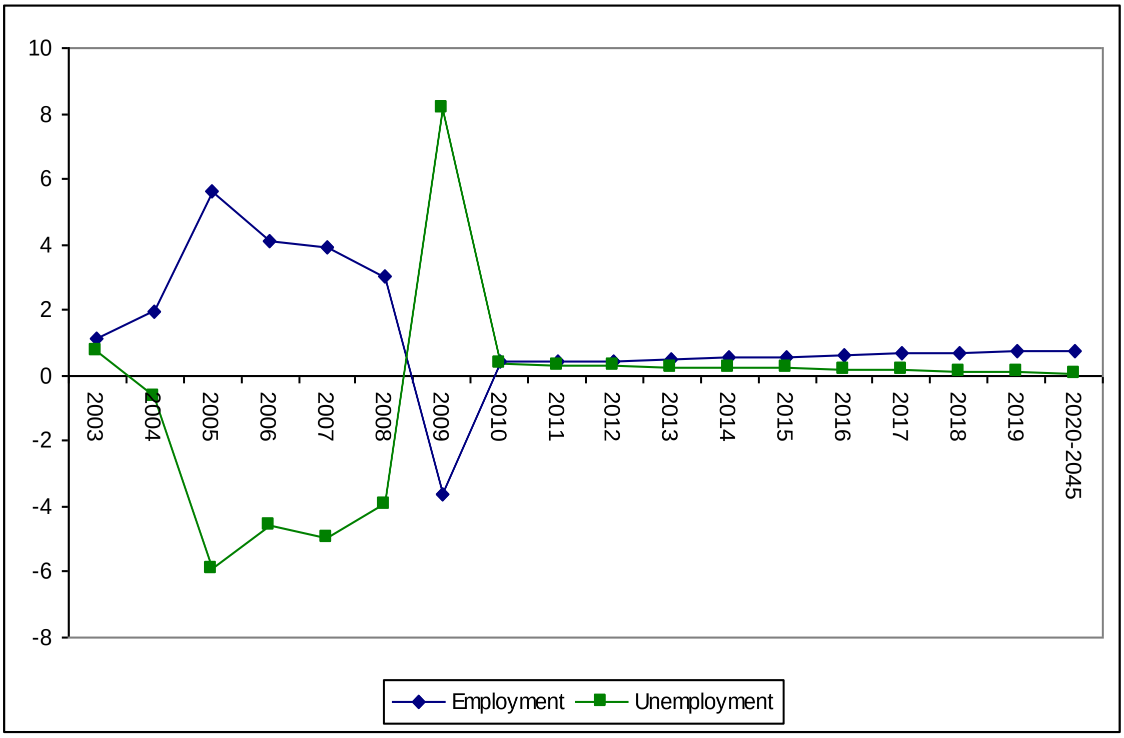
Recall that people who are allocated to the employment, unemployment and new entrant categories offer their labour to an employment activity. Those who fail to secure employment will move to an unemployment activity.[9] Figure 3 reports the year-on-year percentage change in the number of employed and unemployed persons.

For the period 2003 to 2008 I impose relatively strong growth in employment. It is therefore not surprising that the number of people who are unemployed falls during this period. During the financial crisis, employment falls by nearly 4 per cent leading to a sharp increase in the number of unemployed adults. The increase in unemployment takes into account that some people who were employed are now unemployed and that new entrants to the labour market who were not successful in securing employment are now also unemployed. From 2010 onwards both the employment and labour supply forecasts are

[7] In our framework, labour force refers to those employed in an occupation, those who are short-term and long-term unemployed and new entrants. Those classified as "permanently departed from the labour force" (PDL) are assumed not to be actively seeking employment and are therefore not included in our definition of the labour force.
[8] The transition matrix implicitly captures age and gender-specific death rates.
[9] An activity can refer to employment, unemployment and not in the labour force.

based on ILO projections. Employment is set to grow at approximately 0.76 per cent per annum and new entrants to the labour force at 0.08 per cent per annum. With the percentage change in the labour supply increasing by less than employment, I project that the employment rate will increase over the simulation period. My projections show that the employment rate increases from 58 per cent in 2002 to approximately 69 per cent in 2045.[10]

Figure 3. Projected employment and unemployment, 2003–2045 (year-on-year percentage change)



3.4.4. HIV-specific projections

In this section I focus on HIV-specific results. Recall from the discussion in Section 5.1.1.1 that I base the forecast of the number of new HIV infections on a study by Rehle *et al.* (2010). They analyse HIV data based on three national household surveys and find that the overall incidence rate declined from 2002 to 2008. The decline in the incidence rate is mainly driven by young adults, especially African females. From 2009 I do not impose any HIV data.

From the discussion in Section 5.1.3.3, recall that when exogenous data on the number of new HIV infections are introduced, I endogenise the behavioural variable regulating the rate

[10] In the baseline simulation the unemployment rate falls from 42 per cent in 2002 to approximately 31 per cent in 2045. The unemployment rate includes both short-term and long-term unemployment.

at which HIV-negative people become HIV positive. This means that to accommodate the decline in the number of new HIV infections, SAGE-H endogenously determines for each labour-market activity by age, gender and race, the transition rate from HIV negative to Stage 1. I do not introduce any exogenous data to alter any of the remaining transition rates. This means that for the entire forecast period, the transition rates from Stage 1 to Stage 2, Stage 2 to Stage 3, Stage 3 to Stage 4 and those who remain in Stage 4 remain constant at their 2002 levels.

The decline in the total number of new HIV cases is illustrated in Figure 4. In 2002 approximately 518,000 people became newly infected compared with 380,000 new infections in 2008. This fall in the number of new HIV infections is consistent with the decline in the transition rate from HIV negative to HIV positive (Stage 1) from 2002 to 2008. The decline in the transition rates is illustrated in Figures 5 and 6.[11]

Figure 4. Projected aggregate number of new HIV infections per year, 2002–2045 (thousands of people)

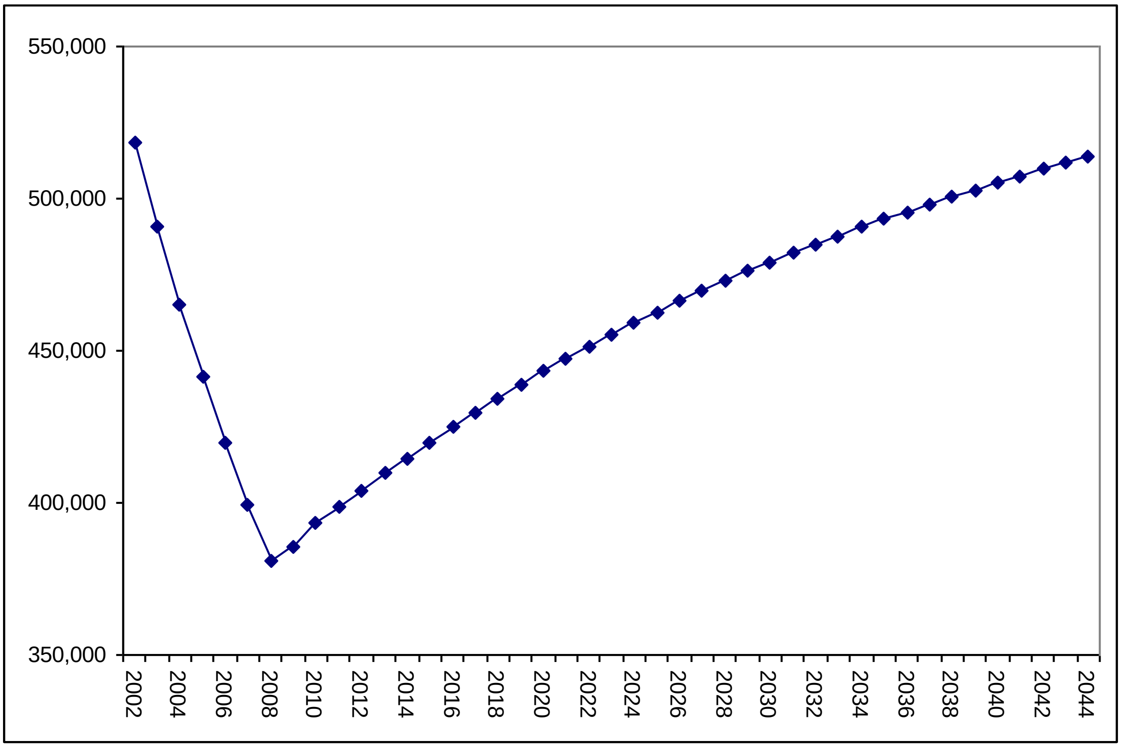


Figure 5 and 6 are specific to the African population because this group reports the highest incidence and prevalence rates. The results for the "Other" population group follow the same age and gender-specific trends observed in Figures 6 and 7. Both figures show that the decline in new HIV infections is driven by the younger age cohorts. The sharp decline in the age and gender-specific incidence rates is mainly due to: (1) the size of the shock

[11] Figures 5 and 6 are the share-weighted sum of all labour-market activities for all age, gender and race elements.

specified in Section 5.3.1.1; and (2) the initial setting of the incidence rates in the base year, reflecting the vulnerability of age groups to becoming HIV positive. The initial setting of the incidence rates suggests that the most vulnerable age groups are 15–24 and 25–34.

Figure 8.5 shows that for females the decline in the probability of becoming HIV positive is driven by the 15–24 age cohort followed by the 25–34 cohort.[12] In 2008 the incidence rate for young females aged 15–24 decreased to 2.8 per cent from approximately 5 per cent in 2002. For males the decline is driven by the 24–34 age group followed by the 15–24 age group. Also shown in Figures 8.5 and 8.6 is that although the incidence rates for young adults fall, they still remain high compared to the other age groups. I therefore project that young adults will account for the largest number of new HIV infections over the forecast period.

From 2008 onwards I do not impose any exogenous HIV data. As a consequence, from 2009 to 2045 the probability of moving from HIV negative to HIV positive (Stage 1) remains constant at their 2008 values. The constant transition rate from HIV negative to HIV positive (Stage 1) combined with the increase in the labour force implies that from 2009 onwards there is a gradual, positive increase in the annual number of new HIV cases, with approximately 505,000 new HIV infections in 2045. This gradual increase is illustrated in Figure 4 and is not due to an increase in the incidence rates but rather that the pool of HIV-negative people, that is, those who are vulnerable, becomes larger over time.

[12] This result is not surprising because African females between the age of 15 and 24 are the group with the highest transition rate from HIV negative to Stage 1.

Figure 5. Projected transition rate from HIV negative to HIV positive for African Females by age group (2002–2045) (ordinary change)

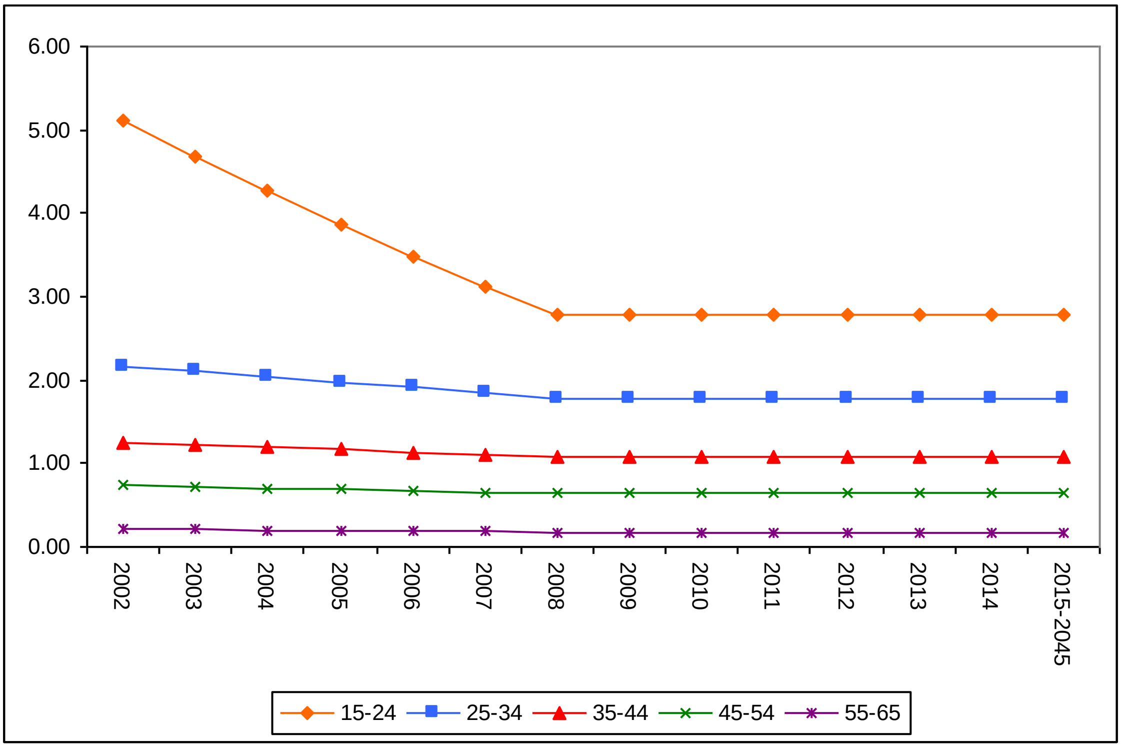


Figure 6. Projected transition rate from HIV negative to HIV positive for African Males by age group (2002–2045) (ordinary change)

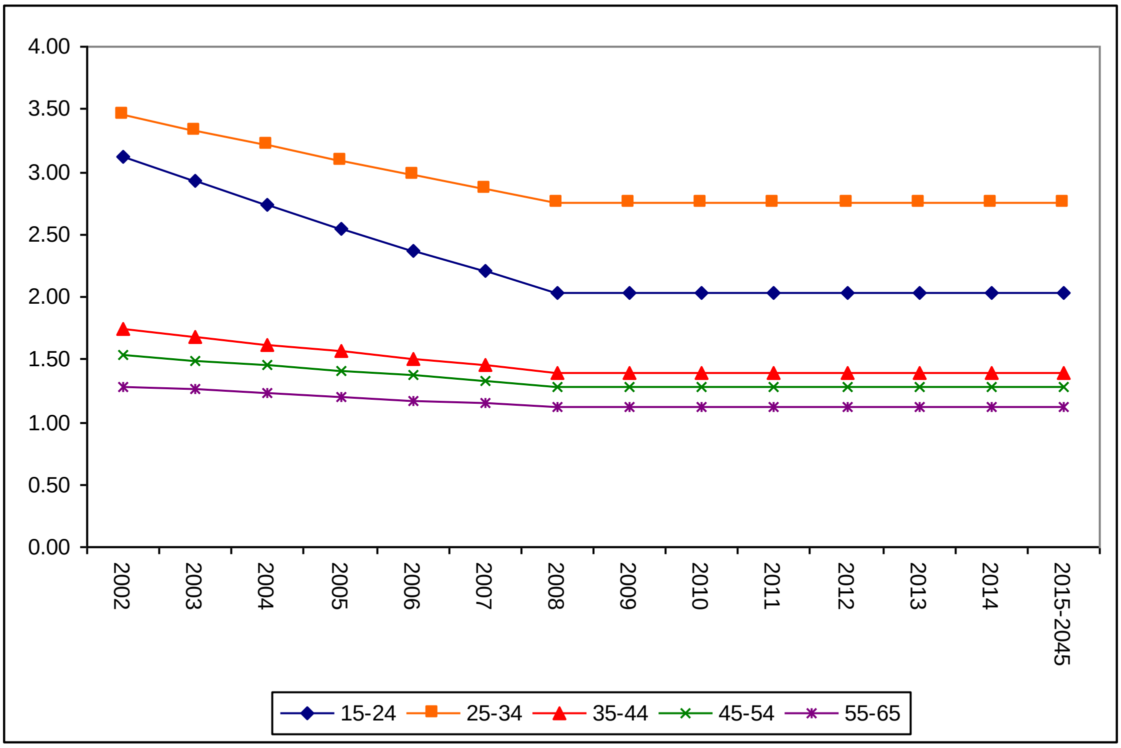


Figure 7. Projected number of people aged 15–65 based on their HIV status (2002–2045) (millions of people)

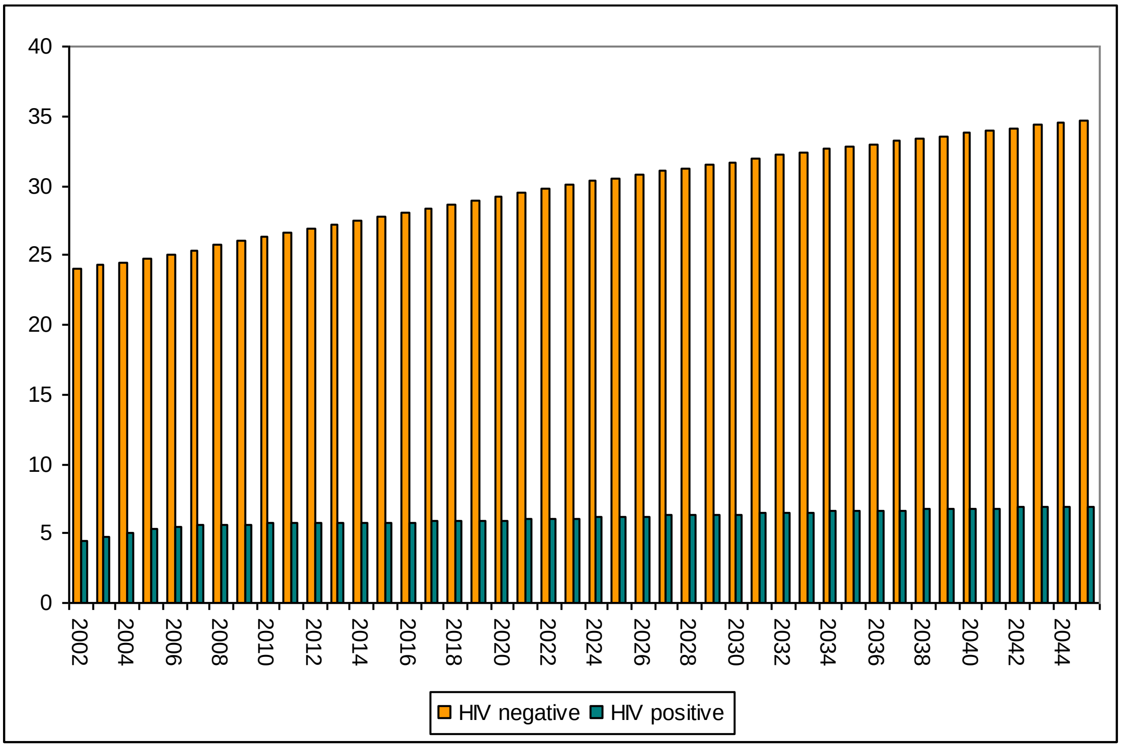


Figure 7 shows the number of people by HIV status. I project that the total number of HIV-infected people will increase over the forecast period albeit at a slower rate. This is mainly due to the lower age and gender-specific incidence rates, combined with constant rates of transition from Stage 1 through to Stage 4. As mentioned before, the transition rates of HIV-positive people remain at their base-year levels throughout the simulation period.

3.3.5. Comparing the HIV results

As is common with most projections, the longer the projection period, the less reliable the results become. This is true for forecasting the path of the HIV/AIDS epidemic because of the uncertainty of the epidemic and the impact of intervention and treatment.

The aim of this section is to compare the results for the total number of new HIV infections and the prevalence rate under different assumptions, modelled in two separate simulations. In the first simulation I introduce the decline in the number of new HIV infections specified in Section 3.2.1.1. The simulation results are therefore based on the simulation settings discussed in this paper. The second simulation excludes the decline in the number of new HIV infections specified in Section 3.2.1.1. This simulation therefore generates results in the absence of these forecast values. The aim of comparing the results between the two simulations is to show that small changes in incidence rates have a significant, long-term impact on the prevalence rate and the number of new HIV infections per year.

Figure 8. Projected number of new HIV infections per year (thousands of people)

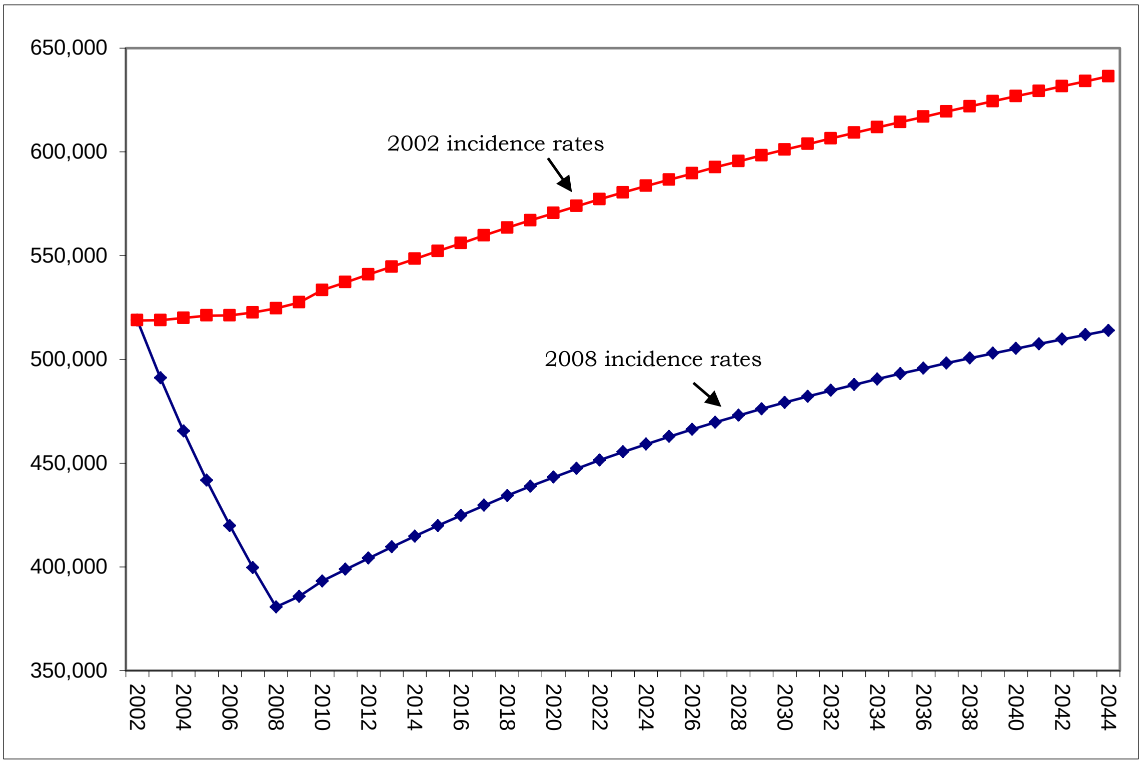
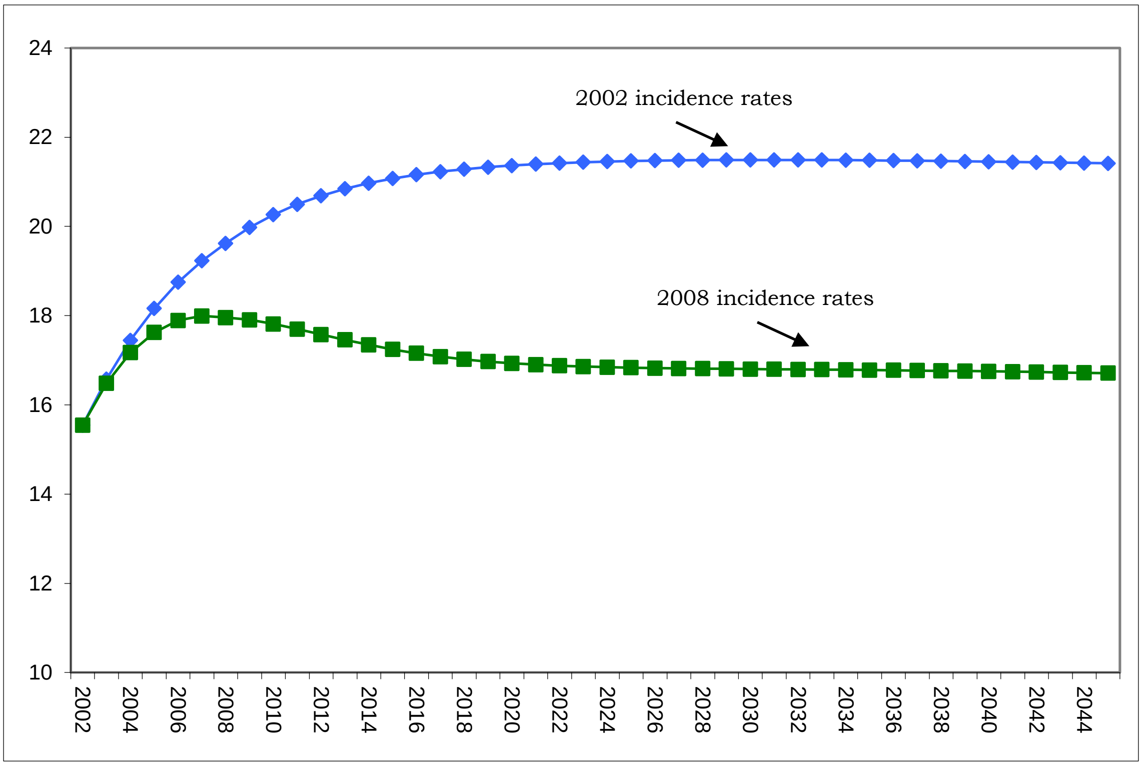


Figure 8 illustrates the number of new HIV infections under different assumptions regarding the incidence rates. If I hold the incidence rates constant at their 2002 values, the annual number of new HIV cases increases from 518,000 people in 2002 to approximately 630,000 people in 2045. By introducing the decline in new HIV cases as specified in Section 3.2.1, the number of new HIV cases falls to approximately 380,000 people in 2008 and gradually increases over the remaining years.

Figure 9 illustrates the projected HIV prevalence rates from 2002 to 2045.[13] I illustrate two paths to show the long-term impact of a decrease in incidence rates, ceteris paribus, on prevalence rates. The first path (blue line) illustrates the prevalence rate if the incidence rates are held constant at their initial 2002 levels, that is, I do not accommodate the decline in new HIV cases as specified in Section 3.2.1.1. With higher incidence rates I expect the number of HIV-positive persons to increase over time. The projection shows that the prevalence rate stabilises at around 21 per cent.

[13] The prevalence rate is defined as the total number of HIV-positive people in the total population.

Figure 9. Projected HIV prevalence for people aged 15–65 (2002–2045) (percentage)



The second path (green line) illustrates the prevalence rate associated with the lower age and gender-specific incidence rates specified in Section 5.3.1.1. If the incidence rates remain constant at their 2008 levels, the baseline simulation shows that HIV prevalence stabilises at around 16.7 per cent. This is broadly consistent with the South African population estimates, which state that for 2010 the prevalence rate for adults between the ages of 15 and 49 is 17 per cent (Statistics South Africa, 2010a: 3). The mid-year population estimates further suggest that the total number of new HIV infections for 2010 is estimated at 410,000, of which 40,000 are children. Hence, approximately 370,000 adults are newly infected by the HIV virus (Statistics South Africa, 2010a: 8). This is very close to the base results generated by SAGE-H, which suggests that 380,000 adults became newly infected with HIV in 2010.

Our projections therefore suggest that: (1) lowering incidence rates through prevention policies have long-term impacts on the prevalence rates; (2) the prevalence rates stabilise and do not show any decline; and (3) HIV will be present and well established in South Africa, with more than 16 per cent of the working age population infected.

4. CONCLUDING REMARKS

This paper describes the BOTE model, which is a stylised version of SAGE-H. BOTE describes the macroeconomic relationships in SAGE-H and will be used to understand simulation settings, identify the main mechanisms operating during simulations and assist with the explanation of simulation results.

This paper also describes the development of the baseline forecast for the South African economy from 2002 to 2045. The baseline forecast simulation simulates the growth of the South African economy and tracks the HIV epidemic over the simulation period. This simulation reflects the business-as-usual scenario in the absence of any policy intervention.

Due to the availability of observed and independent forecast data, I develop three forecast closures for the baseline simulation. The first closure, Forecast closure 1 (FC1), is developed for the period 2002–2009. During this period I impose observed data on a number of macroeconomic variables and the number of new HIV infections. The second closure, Forecast closure 2 (FC2) is developed for the period 2010–2014. In this closure I exogenise variables for which independent forecast data are available. The third closure, Forecast closure 3 (FC3) is developed for years 2015–2045. For this period, no independent forecast data are available. I forecast GDP, aggregate employment, real wages and new entrants to the labour force during this period. I assume that these variables grow at a constant annual growth rate based on past trends.

My forecast anticipates continued high rates of growth for the South African economy. This largely reflects the use of observed and independent (IDC) forecasts for all the expenditure components, aggregate employment, real wages to 2014, and the assumption of a continuation of certain features of the IDC's forecasts from 2015 to 2045. The imposed data forecast an annual average real GDP growth rate to 2014 of 3.3 per cent. With high investment forecasts imposed, SAGE-H estimates growth in the capital stock. By imposing ILO's population forecasts, the labour force is allowed to grow over the simulation period. By combining the employment and the growth in the labour force data, SAGE-H estimates not only the change in the number of unemployed persons, but also a gradual decline in the unemployment rate (alternatively an increase in the employment rate). I also impose on the model the decline in the number of new HIV infections for the period 2003–2008. SAGE-H shows that the probability of an adult moving from HIV negative to HIV positive declines over this period, which is consistent with the HIV forecast.

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