



## Impact of HIV/AIDS on Saving Behaviour in South Africa

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# Impact of HIV/AIDS on saving behaviour in South Africa

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## Abstract

The models measuring the macroeconomic impact of HIV/AIDS are heterogeneous : each one relies on a specific theoretical background. Nevertheless, there are, at least, three main common limits to those approaches : the authors concentrate on the impact on the labour market ; they neglect the potential implications on the capital market ; and they do not model some essential microeconomic impacts such as the change in the agents' economic behaviour. More specifically, the analysis of the impact of HIV/AIDS on savings takes into account direct costs such as health expenditures, seldom indirect costs like the anticipation of funeral costs and they do not model differed indirect costs. The paper proposes an analysis of this last kind of implications through the impact of the epidemic on the saving behaviour.

This paper focuses on the uncertainty of life expectancy and is based on two frameworks: the Galí (1990) model which considers the life cycle theory with a finite horizon at the aggregate level and the Moresi (1999) model which specifies a peculiar consumption utility function through uncertain lifetime.

The calibration and simulations of our model reveal a significant drop in the future saving rate in South Africa under the hypothesis of a virus evolution similar to the one given by the UN Population Division : the saving rate in 2015, under those hypothesis, should be at least 5 percentage points inferior to the estimated saving rate that would then prevail in the absence of the epidemic.

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# 1 Introduction

In the analysis of the implications of HIV/AIDS on the Southern African economy, several microeconomic impact papers exist to assess the consequences of the epidemic. They generally focus on the economic implications of the virus on firms<sup>1</sup> and do not observe the link between households and HIV/AIDS<sup>2</sup>. Fewer works try to estimate the impact at the macroeconomic level. However, the ING Barings (2000) estimates that the epidemic will cut South Africa's annual growth rate by 0.3 and 0.4 percentage points during the periods 2006-2010 and 2011-2015 respectively. The estimates of Arndt and Lewis (2000) predict an even more pessimistic burden : the differences between the real growth rates in the no AIDS scenario and the AIDS scenario reach a maximum value of 2.6% in 2008. The lack of quantification at the macroeconomic level of the impact of the virus is not specific to South Africa : the modelling of the macroeconomic impact of the HIV/AIDS is recent, scarce and heterogeneous<sup>3</sup>.

One consequence of this has been the early giving up of macroeconomic approaches and the multiplication of descriptive sectorial analysis during the nineties for several countries. The considerable proportions that took the epidemic during the last decade and the growing necessity to evaluate its implications at the global level recently renewed the interest for the macroeconomic approaches. The two studies previously quoted can be considered as illustrations of this revival.

Nevertheless, those works underestimate the impact by focusing on direct effects, in particular on the labour factor, by minimising indirect costs such as the absenteeism of the relatives of a sick person and by excluding differed indirect costs<sup>4</sup>. Obviously, those critics can be justified by the constant dilemma of the economists between a complex and

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<sup>1</sup>For example, a study from The Southern African Economist (1997) found that at current levels of benefits per employee, the total costs of benefits due to HIV/AIDS would rise from 7% of salaries in 1995 to 19% by 2005.

<sup>2</sup>The first southern african households survey on HIV/AIDS is currently prepared by the Centre for Health Systems Research & Development of the University of Free State and focuses on the burden of the illness and coping strategies of the households. See Booysen and Bachmann (2002).

<sup>3</sup>The first papers were applying the Rice (1967) approach of cost estimates : Over, Bertozzi and Chin (1989) used this framework to estimate the costs caused by a case of HIV infection in Zaire and Tanzania and Broomberg *et al* (1991) followed the same methodology for South Africa. Those short run estimates were partial and soon completed by new approaches : Over (1992) tried to estimate the fall in the GDP consequent on the epidemic through a simple production function ; the computable general equilibrium model of Kambou, Devarajan and Over (1992) for Cameroon simulated a static and dynamic impact of HIV/AIDS on GDP and several other macroeconomic variables ; Cuddington (1993a) (1993b) and Cuddington and Hancock (1994) (1995) proposed different models based on a Solow growth theory and applied them to Tanzania and Malawi ; the ING Barings (2000), quoted before, used a supply/demand model for South Africa. This sample of models is not exhaustive but testifies that an appropriate method to estimate the macroeconomic impact of HIV/AIDS may be missing. There is no consensus on the best theoretical background to estimate the impact of the virus.

<sup>4</sup>The term "differed indirect costs" is due to Touzé and Ventelou (2002).

a simple specification. This argument weakens in front of two particular dimensions of the epidemic today : the political and human implications of an underestimation of the impact ; and the multiplicity of the potential effects of the virus on the economic sphere. Therefore, the analysis of the impact of HIV/AIDS should try to take into account a broader range of impacts, affecting all markets rather than simply the labour market. They should propose bridges between the production factors and economic growth and between the micro and the macro scales of the effects of the virus.

In this paper we propose to study one potential differed indirect cost, namely the impact on private saving behaviour of a higher annual probability of death due to HIV/AIDS. The aim is on the one hand to complete macroeconomic models with an aggregate form of the consumption decision including HIV/AIDS parameters and on the other hand to go deeper on the understanding of the potential microeconomic incidence of the virus on households. We precise that the paper deals with one specific impact of the epidemic on private savings : the change in the intertemporal consumption behaviour due to a higher annual probability of death. It models neither the increase in health care nor the anticipated funeral costs, potential impacts generally considered as the only incidence of the virus on savings. It does not analyse other intertemporal impacts such as the intergenerational costs due to the emergence of orphans in the households.

We show that the impact of a higher annual probability of death due to HIV/AIDS will be likely quite high. Therefore, neglecting such an impact may significantly minimise the overall incidence of the epidemic on growth. The model used is an aggregate version of the life cycle theory under lifetime uncertainty. Among the available saving theories, this framework best corresponds to the simple intuition that motivated the paper : in a country where the epidemic is generalized, the individuals facing a high probability to be infected will change their views of the future and in particular their consumption strategy. They will probably take into account three features of the virus : a reduction of their productivity, and then of their income ; the coming of the period of inactivity sooner than in absence of the virus ; and the number of years of inactivity cut to the last years of illness. Thus, the theory initially developed by Ando and Modigliani (1963) and soon completed by Yaari (1965) who introduced in the analysis the uncertainty on the lifetime, appeared to be appropriate in considering those micro implications of the HIV/AIDS. The paper is based on Gali (1990) and follows its way of modelling the optimal aggregate saving behaviour in an environment where the consumer is subject to an annual probability of death. But this framework is completed using a paper by Moresi (1999) : contrary to the papers traditionally considering a standard expected utility, it describes specific preferences when the consumer faces dynamic choice problems under uncertain lifetime.

The main result is that the absence of any HIV/AIDS policy will generate a significant drop in the saving behaviour of the consumers in South Africa for the period 2000-2015 : in 2015 the HIV/AIDS would cut 5 percentage points to the saving rate only through

its impact on private savings. Nevertheless, if the government develops a coping strategy such as an extended prevention program or a moderate treatment experience, the saving rate will admittedly reach higher levels but will never converge in the long run on the saving rates that would have prevailed in the absence of the epidemic.

## **2 Optimal individual behaviour of a consumer under uncertain lifetime**

The specification of the optimal individual saving behaviour considered in the paper is a discrete version of the utility function for dynamic choice problems under uncertain lifetime established by Moresi (1999).

### **2.1 The individual maximization program**

The impact analysed in this paper could be considered as the consequence of a general sullenness and concern due to the repeated illness and funerals of individuals. This impact is valid for the overall population both directly affected and not directly affected. The main intuition behind this assumption is that it appears more relevant to consider, when analysing the changes in the decisions of the individuals, that the population should not be divided only into affected and not affected agents but also between agents aware of their serostatus and agents ignoring it. More precisely, we consider the following statements : the agents who know they are not affected will not significantly change their behaviours in the short run ; the saving decision of the individuals who know they are affected is unspecified and should be inferred from household surveys ; the agents who ignore their serostatus but who are conscious because of the repeated presence of the illness in their lives that they face a high probability to be affected or to get affected in the future will probably change the anticipated length of their life cycles and their income distribution between consumption and savings. According to this intuition, the impact analysis, in particular at the micro level, should not be limited to affected individuals defined as persons living with HIV/AIDS : when the epidemic is generalized the overall population will change its behaviour. This hypothesis of an impact on the overall population is all the more important that most Southern Africans ignore their serostatus but live in a country where the epidemic is generalized. Consequently, we will focus on this global impact and will not conclude on the impact of HIV/AIDS on affected agents who know their serostatus.

The formalization of this intuition requires to consider each agent as a consumer and to define the utility function and the budget constraint of each one in order to determine the individual optimal consumption strategy. The theoretical framework of Moresi(1999) is useful to assess the impact on savings that we are considering, namely the impact of an

increased annual probability of death, but can be completed to take into account direct, indirect and differed indirect implications of HIV/AIDS on savings and to measure the overall implications of the epidemic on savings.

The choice of Moresi (1999) individual maximization program is motivated by the fact that this author contests the use of standard utility functions such as quadratic functions in the analysis of the optimal individual consumption under uncertain lifetime and sets that it is more relevant, in that case, to model a specific form of the preferences that would be appropriate to the analysis of epidemics such as the HIV/AIDS pandemic. The preferences are calculated under the ordinal certainty equivalent hypothesis and chosen to be time consistent.

Let the utility function at time  $t$  of a consumer born in period  $s$  be represented by  $V_{s,t}$  and take the form :

$$V_{s,t} = \sum_{j=0}^{\infty} (1 + \delta)^{-j} (1 - p)^{\frac{j\rho}{\gamma}} c_{s,t+j}^{\rho} \quad (1)$$

for  $j \in [0; \infty[$  and where  $\delta$  is the discount rate,  $\delta \in [0; 1]$ ,  $p$  is the constant probability to die between period  $t$  and  $t + 1$  such as  $p \in [0; 1]$ ,  $c_{s,t}$  is the individual consumption at  $t$  of a consumer born at period  $s$ ,  $\rho$  and  $\gamma$  are two parameters such as  $0 < \rho < 1$  and  $\gamma > 0$ . Considering that  $(1 + \delta)^{-j}$  is the discount factor between the periods  $t$  and  $t + j$ , and that  $(1 - p)^j$  represents the probability of being alive at time  $t + j$ , the utility function of the consumer is no more than an actualisation of a preference function of the form  $U(c_{s,t}) = (1 - p)^{\frac{t}{\gamma}} c_{s,t}^{\rho}$  that takes into account the finite horizon of the individual life. Following the general life cycle theory, the utility of the consumer depends on future levels of consumption, on the opportunity to consume and on the potential realization of the future consumption levels. Obviously this last point will be influenced by the subjective probability of death of each consumer. The sullenness attributable to the generalization of the HIV/AIDS epidemic will alter the subjective probability of death. According to Moresi, the concern will also change intrinsically the preference function associated with each consumption level : in presence of uncertainty on the probability of death, the annual utility is individually influenced by the impact of HIV/AIDS on life expectancy.

The dynamic budget constraint that is associated to the utility function is given by :

$$W_{s,t+j} = W_{s,t+j-1}(1 + z) + yl_{s,t+j} - c_{s,t+j}$$

where  $W_{s,t}$  is the non human wealth at time  $t$  of a cohort born in period  $s$ ,  $z$  is the individual effective gross return defined as  $(1 + z) = (1 + r)(1 - p)$  and  $yl_{s,t}$  is the individual labour income at time  $t$  of a consumer born in period  $s$ . The definition of  $z$  introduces the redistribution within a cohort of the cumulated wealth of a deceased member of the cohort. This constraint suggests that the individuals can borrow or lend to a financial system so that their consumption can be smoothed during their lifetime. One precision must be made : the financial wealth is observed at the end of each period so that the interest rate corresponds to the current period.

As a consequence, in order to solve for the optimal individual consumption, the maximization program to take into account is :

$$\begin{cases} \text{Max} \sum_{j=0}^{\infty} (1 + \delta)^{-j} (1 - p)^{\frac{j\rho}{\gamma}} c_{s,t+j}^{\rho} \\ W_{s,t+j} = W_{s,t+j-1}(1 + z) + yl_{s,t+j} - c_{s,t+j} \end{cases}$$

The program suggests that the consumer knows almost all the elements of the intertemporal choice with certainty : the consumption levels, the preference form, the discount rate and the probability to die are known under a budget constraint where the accumulated wealth and the future revenues are also known. The uncertainty is only present in the fact that the true and not the average horizon of life is unknown.

This simplified formalization could be completed by introducing other dimensions of the uncertainty like the uncertainty on the discount rate underlined by Levhari and Mirman (1977) or on the future revenues analysed by Flavin (1981). But these additional dimensions could have divergent effects on the saving rate. Consequently in the paper, we focus only on the uncertainty on the lifetime.

## 2.2 The individual form of consumption

The resolution of this program (Appendix 1) leads to the basic consumption function :

$$c_{s,t} = v (W_{s,t} + H_{s,t}) \quad (2)$$

where  $v$  is a linear coefficient and  $H_{s,t}$  is the human wealth at time  $t$  of a consumer born in period  $s$ . Like in most standard consumer models, the current individual consumption is a linear function of the current individual non human wealth or financial wealth  $W_{s,t}$  and of the current individual human wealth  $H_{s,t}$ .

Nevertheless, introducing the specific preferences given by Moresi (1999), the human wealth and the linear coefficient are different from the ones considered by Gali (1990). The individual human wealth is here defined as :

$$H_{s,t} = \sum_{j=0}^{\infty} (1 + z)^{-j} yl_{s,t+j} \quad (3)$$

Given the fact that we do not combine the impact of HIV/AIDS on the uncertainty on the lifetime and on the individual labour income, the only implication of the epidemic on the individual human wealth is the change in the individual effective gross return due to the wealth redistributed after the death of a peer.

The linear coefficient associated to the individual financial wealth and the individual human wealth is expressed as :

$$v \equiv \left[ \sum_{j=0}^{\infty} (1 + z)^{\frac{j\rho}{1-\rho}} (1 - p)^{\frac{j\rho}{\gamma(1-\rho)}} (1 + \delta)^{\frac{-j}{1-\rho}} \right]^{-1}$$

The human wealth takes a very intuitive form : it is the sum of the actualized future individual labour incomes. Consequently, even if a dimension of uncertainty and specific preferences are introduced in the analysis of individual saving behaviour, the model leads to a very simple form of the consumption function. The only difficulty is to determine the value of the parameters, in particular  $\gamma$  and  $\rho$ .

### 3 Optimal aggregate consumption with uncertainty on the lifetime

Following Gali's aggregate life cycle model and introducing the optimal individual behaviour of a consumer under uncertain lifetime formalized in the previous section, the aggregate consumption function can be expressed in particular as a function of the annual probability of death.

#### 3.1 Characteristics of the aggregate consumption function

Gali (1990) develops a discrete-time, quadratic-utility, open economy version of the overlapping-generations framework in Blanchard (1985). The purpose of this section is to aggregate, under Gali's framework, the impact of the epidemic on the subjective probability of death that was described in the previous section. One of the simplifications of the aggregation is to consider that all the agents have the same subjective annual probability of death : it corresponds to the objective annual probability of death calculated from the national life expectancy. We still focus on this sole impact to isolate its implications at the national level. Obviously, it would be interesting to assess the overall impact of the epidemic by completing the model with other macro economic consequences of HIV/AIDS. Here, the key transition element from the micro framework to the macro model is the definition of the aggregate consumption function.

The aggregate consumption is the sum of the consumption of the different cohorts. From this definition, the aggregate consumption can be written as :

$$C_t \equiv \sum_{s=-\infty}^t c_{s,t} N_{s,t} \quad (4)$$

where  $N_{s,t}$  is the size at time  $t$  of the cohort born in period  $s$ ,  $t \geq s$ .  $N_{s,t}$  is declining at rate  $p$  from the initial size of the cohort at birth normalized to  $p$  so that  $N_{s,t} = p(1-p)^{(t-s)}$ . This definition leads to a normalization of the general population, sum of all the cohorts, to one.

Replacing the individual consumption in the definition of the aggregate consumption (4) by the optimal individual consumption characterized by (2), and defining the non-human and human aggregate wealth respectively by  $W_t = \sum_{s=-\infty}^t W_{s,t} N_{s,t}$  and  $H_t =$



$\sum_{s=-\infty}^t H_{s,t} N_{s,t}$ , the aggregate consumption can be rewritten as :

$$C_t = v [W_t + H_t] \quad (5)$$

In order to detail the form of this aggregate function, the aggregate human wealth can be specified by replacing in its definition the individual non human wealth by (3) so that:

$$H_t = \sum_{s=-\infty}^t \sum_{j=0}^{\infty} (1+z)^{-j} y_{l_{s,t+j}} N_{s,t} \quad (6)$$

The individual labour income can be expressed as a function of the aggregate labour income<sup>5</sup> :

$$y_{l_{s,t}} = L_{s,t} y_l = \frac{\Gamma}{p} (1-\alpha)^{t-s} y_l \quad (7)$$

where  $L_{s,t}$  is the individual labour services at time  $t$  of the cohort born in period  $s$ ,  $y_l$  is the aggregate labour income at time  $t$ ,  $\Gamma$  is defined as  $\Gamma = (1 - (1 - \alpha)(1 - p))$  and  $\alpha$  represents the constant annual rate of decline in the individual labour supply during the lifetime of the consumers.

Those definitions allow to replace in the aggregate non human wealth (6), on the one hand the individual labour income by (7) and on the other hand the size of the cohorts  $N_{s,t}$  by its definition. The aggregate human wealth can then be expressed as :

$$H_t = \sum_{j=0}^{\infty} (1+z)^{-j} (1-\alpha)^j y_{l_{t+j}} \quad (8)$$

Thus, the aggregate human wealth takes also a simple form : it is the present value of labour income discounted at the rate  $\frac{1+z}{1-\alpha}$ .

Considering that the aggregate labour income is increasing annually by  $\tau$ , it is interesting to replace the aggregate human wealth in (5) by the expression (8) and the aggregate labour income at time  $t+j$  by  $y_{l_{t+j}} = y_l + \tau j$ . Consequently, the aggregate consumption satisfies, after some manipulations :

$$C_t = vW_t + v \frac{1+z}{z+\alpha} y_l + v\tau \frac{1+z}{z+\alpha} \frac{1-\alpha}{z+\alpha}$$

Letting  $\beta$  be defined as  $\beta = v \frac{1+z}{z+\alpha}$  and  $\Omega$  as  $\Omega = \beta\tau \frac{1-\alpha}{z+\alpha}$ , the consumption function takes the simple form :

$$C_t = vW_t + \beta y_l + \Omega \quad (9)$$

The introduction in Gali's model of an appropriate form of the preferences does not change fundamentally the characterization of the consumption function : it takes the

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<sup>5</sup>see footnote 6 in Gali(1990).

usual form of a linear function of the aggregate non human wealth and of the labour income. Nevertheless, the introduction of new parameters  $\rho$  and  $\gamma$  present in the function through  $v$  leads to a more precise optimal consumption level under uncertain lifetime. Following the restriction to analyse only the implications of the epidemic on savings through the uncertainty on the annual probability of death, the only elements of the aggregate consumption that are not influenced directly by HIV/AIDS are the non-human aggregate wealth and the aggregate labour income. Contrary to the individual financial wealth, the aggregate financial wealth is not directly influenced as the extra wealth due to the redistribution effect after the death of a peer is not valid at the aggregate level.

### 3.2 Identification of a long run aggregate consumption function

In order to simulate different scenarios of evolution of the epidemic, the consumption function must be expressed in the long run. This perspective supposes that the expression (9) is not appropriate and that a function including a recurrent relationship between the consumption at time  $t$  and  $t - 1$  would lead to a long run specification. To make it possible Gali (1990) decomposes the consumption as follows :

$$C_t = \sum_{s=-\infty}^{t-1} c_{s,t} N_{s,t} + N_{t,t} c_{t,t} \quad (10)$$

The aggregate consumption is the sum of the consumption at time  $t$  of the agents born before  $t$  and of the agents born at  $t$ . Considering that the individual consumption at time  $t$  is similar on average to the individual consumption at time  $t - 1$  and deducing from the definition of  $N_{s,t}$  that  $N_{t,t} = p$  and  $N_{s,t} = (1 - p)N_{s,t-1}$ , the aggregate consumption satisfies :

$$C_t = (1 - p) C_{t-1} + p c_{t,t} \quad (11)$$

Specifying that, at time  $t$ , the agents born at period  $t$  have no financial wealth, the current individual consumption of the agents born in the current year depends only on the current individual human wealth. Thus :

$$c_{t,t} = v H_{t,t} = v \sum_{j=0}^{\infty} (1 + z)^{-j} y l_{t,t+j} \quad (12)$$

From (7), the labour income at time  $t + j$  of an agent born at period  $t$  can be easily introduced in the last expression. As the aggregate labour income is increasing annually by  $\tau$ , those manipulations lead to the following consumption function at time  $t$  :

$$c_{t,t} = \beta \frac{\Gamma}{p} y l_t + \Omega \frac{\Gamma}{p} \quad (13)$$

Using (13) and the fact that the current labour income can be expressed as  $yl_t = yl_{t-1} + \tau$ , the general decomposition of the aggregate current consumption (11) can be written as :

$$C_t = (1 - p) C_{t-1} + \Gamma\beta yl_t + \Gamma\Omega(1 + z)(1 - \alpha)^{-1} \quad (14)$$

This last equation is the expression of the long run aggregate consumption. The consumption is a linear function of the past consumption and of the current income revenue. This representation of the optimal aggregate consumption behaviour is similar to the expression derived by Gali (1990) except that in our model the coefficients  $\beta$  and  $\Omega$  include parameters from the Moresi (1999) approach of the preferences under uncertain lifetime.

Exept the uncertainty on future labour income, the HIV/AIDS epidemic could affect the aggregate consumption formalization (14) through three potential impacts . The first one would be a worsening of the potential annual decline in the individual labour supply as the epidemic generates a growing morbidity and a decline in the labour productivity of the individuals. The second potential impact could be the increase in the discount rate. The last one is the impact on the probability of death. The paper will mainly simulate the aggravation of the probability of death due to HIV/AIDS.

## 4 Data and calibration of the model

The calibration of the consumption function means to determine the value of the parameters of the model : the probability of death  $p$ , the annual income growth rate  $\tau$ , the interest rate  $r$ , the discount rate  $\delta$ , the rate of decline in the individual labour supply  $\alpha$ , the parameters  $\rho$  and  $\gamma$  of the preference function.

### 4.1 Calibration of the model

The calibration of the model will follow the methodology of Gali (1990). But the presence in the model of several additional parameters requires to make new assumptions.

The model is applied to the Republic of South Africa for two main reasons : this country represents one of the most HIV/AIDS affected countries in the world<sup>6</sup> and its

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<sup>6</sup>The Department of Health of the Republic of South Africa (2000) revealed that the seroprevalence, the percentage of persons infected with HIV/AIDS, was 24,5% in the population of the women who visited the public health facilities. This data is the last one available on the extend of the epidemic in South Africa. At the national level and for the whole population, the prevalence in the adult population was estimated at the end of 1999 by UNAIDS(2000) at 19,94%, the fifth highest level of seroprevalence after Botswana, Swaziland, Zimbabwe and Lesotho. The demographic impact of such a pandemic can be illustrated by the fall in the expected life expectancy at birth with and without HIV/AIDS : the UN Population Division(2001) estimates that this indicator will be in average of 47,7 years for the period 2000-2005 and would have been for this period of 65,8 years if the epidemic would not have affected the

saving rates already threaten its growth<sup>7</sup>. The data series used are the GDP and the private consumption of the International Monetary Fund (2000) for the period 1970-1999. The objective probability of death is the reciprocal of the annual life expectancy of the consumers. The life expectancy considered here is the sample mean of the life expectancy for the period 1970-2000 calculated from the UN Population Division Database. The annual income growth rate is the sample mean of the annual income growth rate of the period 1970-1999. The interest rate is calculated as the sample mean of  $\frac{W_t - y_t + c_t}{W_{t-1}} - 1$ . The discount rate is supposed to equal the interest rate. The rate of decline in the individual labour supply is determined from the definition of  $\beta$ ,  $\beta = v \frac{1+z}{z+\alpha}$ .

Probability of death $p$	1.76%
Interest rate $r$	5.35%
Discount rate $\delta$	5.35%
Rate of decline in the individual labour supply $\alpha$	0.004
Parameter $\rho$	0.7
Parameter $\gamma$	0.5

Table 1: Calibration of the parameters

The solution chosen to calibrate  $\beta$  is similar to Gali's : the long run behaviour of the aggregate wealth leads to a simple relation between  $\beta$ , the interest rate,  $v$ , and the growth rate of the labour income and of the financial wealth. In our model, this relation is  $\beta = 1 - \frac{\Delta W}{\tau}(v - r)$ . Consequently, the calculation of  $r$  and  $\beta$  requires to estimate the financial wealth time series.

The parameters  $\rho$  and  $\gamma$  of the preference function are not directly determined : from the reference article a reasonable value of the rate of decline in the individual labour supply could be equal to 0.004. Thus, the parameters have been determined by successive iterations in order to make the value of  $\alpha$  equal to 0.004. This method also estimated the aggregate labour income : the proportion of the labour income in GDP has been determined to make the annual saving rate consistent with the saving rates of the private sector estimated by the South African Reserve Bank. The main calibration results are presented in Table 1.

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country.

<sup>7</sup>South Africa is a good example of a highly affected country facing low saving rates. Prinsloo(2000) analyses the saving behaviour of the South African economy and insists in the deterioration of the national saving performance since the middle of the eighties : in 1985 the gross saving as percentage of gross domestic product reached 24,6% ; the downward trend led to an aggregate saving rate of 14,8% in 1999. The comparison of this last rate with the saving performance of selected middle income economies leads to the same conclusion : during the nineties, the saving rate of South Africa deteriorated whereas the saving rate of the developing economies improved.

## 4.2 Base line scenario

Three main assumptions define the base line scenario : the first one concerns the period of simulation, the second one the evolution of the labour income and the last one the life expectancy or probability of death. The two first hypothesis give the frame of the different simulations and the last one the nature of the base line scenario. The period of simulation retained is 2000-2015 in order to be consistent with the projections of the UN Population Division. The labour income is supposed to grow at a constant rate equal to the sample mean growth of the labour income for the period 1995-1999.

The last assumption is the most important and identifies the base line scenario. The probability of death of the base line scenario is calculated from the life expectancy given for the periods 2000-2005, 2005-2010 and 2010-2015 by the UN Population Division (2001). This life expectancy is of course the lifetime of the consumers in the presence of the epidemic and represents the number of years a newborn can expect to live if the determinants of the life expectancy are kept unchanged. In other words, it gives the lifetime of the consumer if the determinants of the evolution of the HIV/AIDS are stable in particular if the prevention programs and the treatments initiatives are maintained at their current levels. In the case of South Africa this assumption means that no appropriate national HIV/AIDS policy is initialized and that the government goes on refusing to extend the treatment initiatives.

The results of the simulation of the base line scenario indicate that the private saving rate of South Africa should grow from the initial level of 15.5% of GDP in 1999 to 26.29% of GDP in 2015. After a first phase of rapid growth, the rate is stabilised around 26% of GDP in 2010. The evolution of the saving rate is consistent with the life cycle theory that predicts that the main determinants of the current saving rate are not the current income but the present value of future labour incomes. Consequently, the individuals are supposed to save a large share of their revenue to smooth their consumption.

## 5 Nature of the simulations

The paper will first analyse what would have been the level of the saving rate in the absence of the epidemic : this simulation corresponds to the traditional measure of the impact of HIV/AIDS on an economic variable. Then it will focus on the consequences of an appropriate prevention policy. The last simulation will estimate the effects of two low-level treatment use options on the saving rate. All the simulations are based on the same principle, the introduction of the relevant objective probability of death measuring the effect of the virus. They all differ in the estimated average life expectancy for the period 2000-2015.

The purpose of the scenario without HIV/AIDS is to determine the saving rate that would have prevailed if the epidemic would have not affected the country. Thus the

estimation of the life expectancy in absence of the epidemic for the period 2000-2015 is necessary. This data is calculated again from the projections of the UN Population Division (2001) : the agency provides estimates for the periods 2000-2005 and 2010-2015 of the expectation of life at birth with and without HIV/AIDS for the most affected countries. The data for the Republic of South Africa are 47.4-65.8 years for the period 2000-2005 and 42-69.6 years for the second period. From these values, the life expectancy for the period 2000-2015 without HIV/AIDS is assumed to be equal to 67.6 years. The assumption of the absence of the epidemic is supposed to be valid from the date 2000 and not from the real beginning of the epidemic in South Africa ten years before in order to maintain the calibration of the model.

The second simulation aims at observing to what extent the prevention policies could compensate the significant change anticipated by the model on the consumption behaviour due to the epidemic. Obviously, under the life cycle theory, if any policy, prevention or treatment, lead to a higher life expectancy, the national strategies would enhance saving rates. But here we try first to measure the sensibility of saving rates to different levels of probability of death, and second to observe if these national programs make saving rates converge to the levels that would have prevailed in the absence of the epidemic. Modelling the link between the life expectancy and an active prevention policy means to build a realistic evolution of the probability of death under an appropriate national policy against HIV/AIDS. Thus, the evolution of the life expectancy with an active prevention policy will follow the Ugandan experience<sup>8</sup>. Thus the assumptions guiding the second simulation are : South Africa develops in 2000 the same active prevention strategy as the Ugandan government did in 1990 ; the evolution of the life expectancy from 2000 to 2015 will follow the evolution of the Ugandan life expectancy from 1990 to 2005. The Ugandan data used are from the UN Population Division Database for the periods 1990-2000 and from the UN Population Division (2001) for the estimation of lifetime during the period 2000-2005. Consequently, the Southern African average life expectancy that would prevail during the period 2000-2015 with an active prevention policy is 54.96 years.

Through the last simulation, the objective is to observe the impact on the saving behaviour in South Africa of a low-level use of antiretroviral treatment. The purpose is not to debate the false controversy between prevention and treatment : the purpose is only to use the last data available on the expected effects on the life expectancy in South

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<sup>8</sup>Uganda suffered one of the worst HIV/AIDS epidemic during the 1980s and soon tried to experiment different strategies against the virus. After a first traditional program directed by the Health Ministry and focusing on the HIV/AIDS information to control the disease in the mid-1980s, the Multisectoral Approach on the Control of AIDS (MACA) began in 1992. This new control policy involving all the levels of the society and community in educating, counselling and encouraging the voluntary tests is considered as the major cause for the reduction of the HIV/AIDS seroprevalence observed since a few years in Uganda. After this relative success and several national plans in the spirit of the MACA, Uganda is considered as the pioneer of a control strategy in a country where the resources are scarce and where the epidemic is generalized.

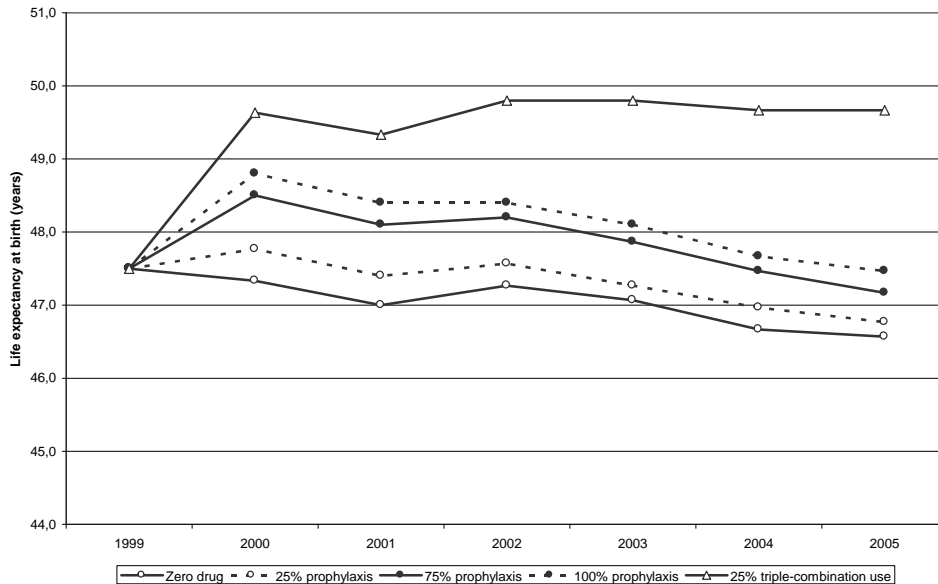


Figure 1: Annual life expectancy projected in scenarios zero to four for South Africa in Wood *et al* (2000)

Africa of the introduction of a low-level treatment policy.

The evolution of the probability of death under a low-level use of antiretroviral treatments is assessed from a work of Wood *et al* (2000) modelling the future impact of antiretroviral use in South Africa from 2000 to 2005. In Wood's work, a scenario with no treatment campaign is compared with four antiretroviral-adjusted scenarios<sup>9</sup>. Our paper will focus on two specific scenarios : the generalised prophylaxis use<sup>10</sup> treatment scenario and the triple-combination treatment scenario. This decision is motivated by the parallel evolution of the life expectancy under the three scenarios based on a prophylaxis treatment as shown in Figure 1. Thus, from Wood's projections, we estimated the evolution of the life expectancy on the one hand if all pregnant women received the prophylaxis treatment and on the other hand if 25% of the adults living with HIV/AIDS were treated. The expected average life expectancy during the period 2000-2015 for the generalised prophylaxis treatment amounts 53.3 years and for the triple-combination treatment is 55.46

<sup>9</sup>The first and second scenarios assume that 25% and 75% respectively of all pregnant women and infants living with HIV/AIDS would receive antiretroviral prophylaxis. In the third scenario all pregnant women would receive the prophylaxis treatment irrespective of their serostatus. The last scenario concerns the impact of triple-combination antiretroviral treatment on 25% of the adults living with HIV/AIDS excluding pregnant women.

<sup>10</sup>Prophylactic use refers to the proportion of HIV-1-positive pregnant women using antiretroviral prophylaxis.

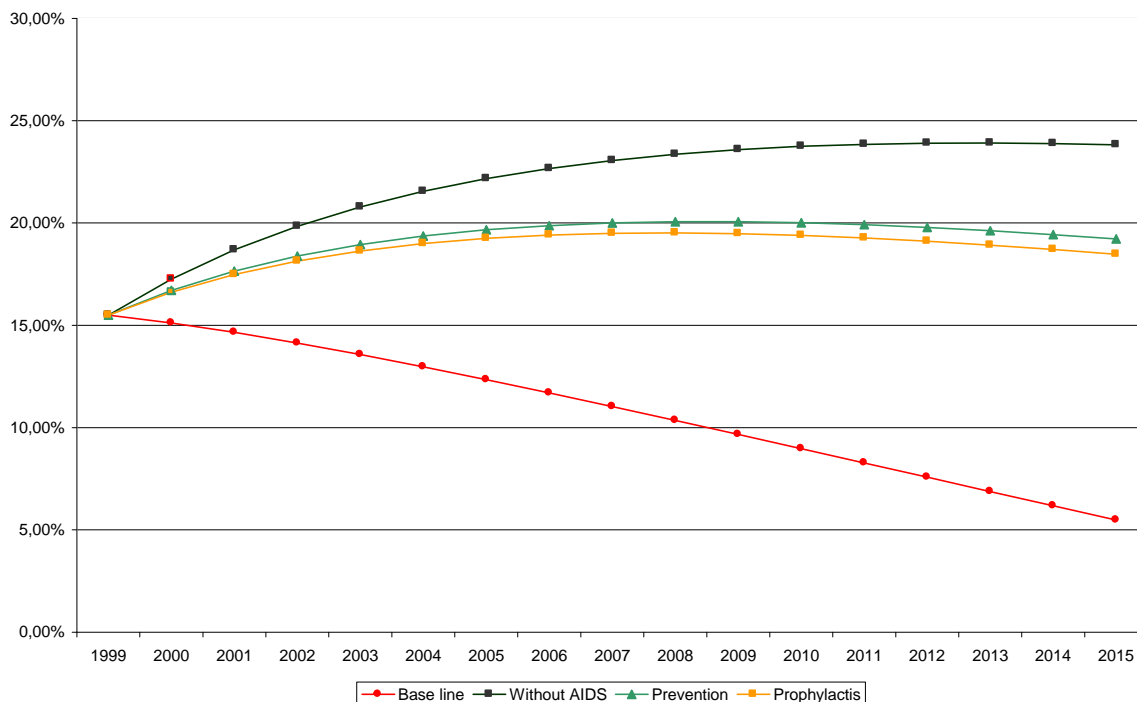


Figure 2: Result of the simulations for the four scenarios and during the period 2000-2015.

years.

## 6 Main results of the simulations

The impact of HIV/AIDS on the saving behaviour in South Africa under the different scenarios are presented in Figure 2 .

The form of the evolution of the saving rates for the scenarios except the baseline one can amaze as the saving rate is growing with time. This trajectory is due in particular to the fact that the life cycle theory states that saving rates should be quite high as consumption is smoothed over time. But as the simulations begin with the low current levels of saving rate in South Africa, the life cycle theory leads to higher levels until a stationary rate at the end of the period. What is interesting actually is the comparison between different scenarios at different periods.

Focusing on the scenario without HIV/AIDS, in the absence of the epidemic the saving rate in South Africa would have been in average eleven percentage points higher than the rate achieved in presence of the epidemic. Moreover, the difference between the two



scenario rates is growing as the period of simulation extends. The maximal difference corresponds to the last year of the period : in 2015 the HIV/AIDS would cut 18 percentage points to the saving rate only through the change in the consumption behaviour of the individuals.

Obviously this effect strongly depends on the value chosen for the parameter. Nevertheless, the potential change in the behaviour due to the anticipation of the lifetime uncertainty could have a significant effect on the saving rate. This result points out the dangers of a simplification of the impact of HIV/AIDS in the macroeconomic impact analysis.

The second main lesson from the results is that although the prevention policy and the initialization of a treatment policy moderate the impact of HIV/AIDS on the saving behaviour, these upturns are not significant enough to completely compensate the cut in the saving rate due to the epidemic. The consumers take into account their lower probability of infection in the long run but in the short run the saving rate is still influenced by the burden of past low life expectancies. Even under different efficient coping strategies, the impact of the initial high mortality due to HIV/AIDS is vivid in the long run.

## 7 Conclusions

The model of life cycle theory under uncertainty on the lifetime reveals that if no national policy against HIV/AIDS is developed in South Africa, the epidemic will be responsible for a significant drop in the saving rate. It also predicts that the different strategies against HIV/AIDS moderate the cut in the lifetime due to the epidemic but do not significantly compensate the years lost. Therefore, this impact should be taken into account in the measure of the economic implications of the virus. The article proposes a standard consumption function with parameters which depend, among other factors, on the probability of death due to HIV/AIDS.

Of course those results are partial and do not incorporate the implications on the global sphere. But their purpose is only to suggest that in the macroeconomic analysis of the HIV/AIDS impact and of the efficiency of the strategies against HIV/AIDS, microeconomic models considering the predicted effects on the economic behaviours should be introduced.

### Appendix 1

The resolution is no more than a discrete version of Moresi (1999) resolution. The continuous program takes the form :

$$\begin{cases} Max V_t(c) = \int_t^\infty D(v, t) P(v, t)^{\frac{\rho}{\alpha}} c(v)^\rho dv \\ \frac{da}{dv} = [r(v) + \lambda(v)] a(v) + y(v) - c(v) \end{cases}$$

where  $V_t$  is the consumer's intertemporal utility function,  $D(v, t)$  is the discount factor between time  $v$  and time  $t$ ,  $P(v, t)$  is the probability of being alive at time  $v$  conditional on being alive at time  $t$ ,  $c(v)$  is the individual consumption at time  $v$ ,  $r(v)$  is the instantaneous interest rate,  $a(v)$  is the individual financial wealth,  $y(v)$  represents the wage income net of taxes and transfers,  $\lambda(v)a(v)$  reflects a complete and competitive annuity market.  $\alpha$  and  $\rho$  are two parameters satisfying :  $\alpha > 0$  and  $0 < \rho < 1$ .

The resolution leads to the individual consumption :

$$c(t) = \gamma(t) [a(t) + h(t)]$$

where  $\gamma(t) = [\int_t^\infty P(v, t)^{1-\sigma+k\sigma} D(v, t)^\sigma R(v, t)^{1-\sigma}]^{-1}$  and  $h(t) = \int_t^\infty P(v, t) R(v, t) y(v) dv$  with  $\sigma = (1 - \rho)^{-1}$ ,  $k = \frac{\rho}{\alpha}$  and  $R(v, t) = \exp(-\int_t^v r(u) du)$ .

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