Analysis of the viability of health insurance in Cote d'Ivoire: A theoretical and empirical study

Kouame Kouakou Romaric
Alassane Ouattara University, Bouake, Côte d'Ivoire, Economic Policy and Modeling Laboratory

Kouassi Patrick Franklin
African Higher School of ICT, Abidjan, Côte d'Ivoire, Information and Communication Technology Science Laboratory

Pandry Koffi Ghyslain
African Higher School of ICT, Abidjan, Côte d'Ivoire, Information and Communication Technology Science Laboratory

Abstract

This article presents a possible use of sustainability tools in the framework of an economic model of a sustainable social health insurance system. Our study proposes to question the sustainability of the social protection system in relation to the Universal Health Coverage policy adopted by the State of Côte d'Ivoire. The objective of this article is to analyse the sustainability of universal health coverage using the mathematical tools of sustainability theory. The theory of sustainability allows the integration of the main characteristics of sustainable insurance. The results of our study show that the Ivorian social insurance system (UHC) cannot be sustained over time. Universal health coverage will not be able to ensure the financial protection of Ivorians in the long term. It will therefore be necessary to rethink its mode of financing and control the rapid growth of the population.

Keywords: Sustainability theory, sustainability kernel, multi-criteria approach, health insurance, intergenerational equity.

Introduction

After independence, the Ivory Coast experienced strong economic growth from which its health system benefited. During this period, the government of the time opted for a policy of total free health care, accommodation costs, drug costs, medical costs of examinations and surgical intervention analysis. This policy of total free health care contributed to the improvement of the population's well-being (HDI from 1970 to 1980).

The 1980s, marked by the economic crisis and the various structural adjustment programs, contributed to a reduction in government revenues and the abandonment of the free health coverage policy in 1980.

After the Bamako initiative (1987), which was based on the search for financial sustainability and equity in health services, partial recovery of health costs was introduced in public health facilities. The government decides that households should contribute to their own health costs. The revenue collected in this way constitutes the health facilities' own resources and supplements the state budget. This policy of household contributions has limited access to basic health services for the most vulnerable and poorest segments of the population and has also encouraged the development of therapeutic treatments and mutual health insurance in the public and private sectors. But this has not led to an insurance system to protect against the risk of illness.

In 1973, the Ivorian government created the MGFAE (General Mutual of Civil Servants and State Agents), which has now become MUGEFCI (General Mutual of Civil Servants and Agents of the Côte d'Ivoire), to remedy the problem of the lack of health coverage for civil servants and government employees, whether active or retired. This was followed by the creation of mutual insurance companies in the private sector and the development of the insurance market.

However, in Côte d'Ivoire, only 3% of the population has health insurance coverage compared to 97% without any health insurance (INS, 2015).

This situation has thus imposed the reflection on the financing of a health insurance system. Thus, Côte d'Ivoire, as part of the objectives of sustainable development, wants to allow its entire population to live in good health and promote the well-being of all at any age, by establishing a system of universal health coverage by Law No. 2014-131of March 24, 2014, creating the UHC. By Decree No. 2014- 395 of June 25, 2014, it created the National Universal Health Insurance Fund (NHIF). The objective aimed by the Government is the extension of health risk coverage to all social strata of the Ivorian population.

This Universal Health Coverage (UHC) system is based mainly on national solidarity through the mutualisation of the health risk and equity of access to care without ethnic, religious or political discrimination. This means that UHC operates using a third-party payment social machine. This mechanism is made up of two main schemes: A contributory scheme and a non-contributory scheme. According to the regulatory provisions, the contributory scheme, called the General Basic Scheme (GBS) is financed by the contributions of the insured up to 1000 CFA francs per month, or 12,000 CFA francs per year and per person. The financing of this plan is fixed and targets the majority of the population. The non-contributory scheme, known as the health insurance scheme (HIS), a scheme for the indigent in which the state substitutes for the latter to pay their contribution. This scheme is fully funded by the state.

On analysis, this first contributory scheme maintains a contradiction or social paradox with respect to the laws of health insurance operation. In fact, in the health insurance clause, the highest payer or the one who contributes more should benefit from more services than the average payer, and so on, depending on the level of financial contribution of the insured. It is announced in the UHC's operating rules that, under the contributory plan, anyone who can prove that he or she has an income will contribute 12,000 CFA francs per year. This would mean that a person who earns a monthly salary of 500,000 CFA francs would pay the same contribution as a person who earns a monthly salary of 60,000 CFA francs, for example. This seems to be in contradiction with the principle of social health insurance, which is that everyone should contribute according to their income and receive according to their needs. There is therefore a problem of equity in the financial contribution of the said insurance. In addition, nearly 46% of Ivorians still live on less than 750 CFA francs per day (World Bank, 2019).

According to the WHO, a well-functioning health financing system, and thus a well-functioning compulsory health insurance system, should have the following objectives

(i) generate sufficient and sustainable resources for health

(ii) Use these resources optimally (by changing incentives and using these resources appropriately)

(iii) Ensure affordability for all.

The implementation of the CMU raises questions about its viability or sustainability: Can we talk about the viability of the Ivorian insurance system when the contribution of individuals receiving insurance benefits is not proportional to their income or purchasing power? How can an individual who lives on less than 750 CFA francs pay a contribution of 1,000 CFA francs per month? Is the financial contribution of 1000 FCFA per person optimal? Is universal health coverage possible in a health system whose financing policy is based solely on the financial contribution of individuals?

To summarize, will this Universal Health Coverage (UHC) policy be sustainable over time? Our study also proposes to question the viability of the social protection system in relation to the Universal Health Coverage policy adopted by the State of Côte d'Ivoire. Our objective is to analyse the sustainability of the universal health coverage system in Côte d'Ivoire. To better appreciate our objective, a hypothesis underlies our reflection. The trajectory of the insurance system does not remain constantly in the core of viability; therefore, the Ivorian social insurance system is not viable.

The rest of the paper is organized into four sections, the first two of which respectively present the literature review with a focus on the theoretical and empirical analysis of sustainability (section 1), the presentation of the study framework (section 2) the analysis methodology (section 3). The results of the simulations using MATLAB will be performed in section 4 followed by the conclusion.

1. Theoretical Analysis of Sustainability

At the outset, it should be made clear that this critical study aims to help policy makers to successfully implement the UHC policy. On this basis, the methodology of the study is based on the theory of mathematical sustainability and its application to the universal health coverage system in Côte d'Ivoire.

The theory of sustainability allows for the integration of the main characteristics of sustainable insurance: the multi-objective approach, the consideration of an infinite time horizon, the possibility of identifying several sustainable policies, the responsiveness of the system and the respect of intergenerational equity. A responsive health system ensures that individuals are treated with sufficient respect and that the system is sufficiently client-oriented, without distinction between different categories of the population. Financial contributions are considered equitable when health care expenses are allocated based on ability to pay rather than risk of illness and should ensure that all are financially protected from that risk. These ultimate goals of responsiveness and equity regarding financial contributions impact the overarching goal of health, just as they are themselves important.

On the state of national health systems in West Africa, several studies have noted problems of equity (Meunier, (1999); Ridde V. (2004); Ridde, (2008); Standing, (2002); Gilson, (2000) and Bicaba & al, (2003). We also note the adaptive difficulties of health innovations such as the Bamako Initiative (Diallo & Sarr, (1997); Jaffré & Sardan, (2000)) and the problems related to the provision of health services (Sy, 1999). National health insurance systems in West Africa are unsustainable (Ndiaye, 2017). There is an increase in financial contributions from households. The health insurance system is not yet based on equitable financing of populations or households. Several authors including (De Koninck & al, (2008), Berghmans, (2009), Salomez, (2010), and Potvin & Jones, (2010)) have also noted the persistence of social inequalities in health. Moreover, public health policies in West Africa have problems of equity (vertical, horizontal and intergenerational) and efficiency in health governance (Ndiaye S., (2012)). They do not resolve social inequalities in health. Vertical equity recommends that more care be given to those with greater need, while horizontal equity recommends equal care for equal need. Intergenerational equity ensures access to care for future generations.

The principle of viability is the study of controlled dynamical systems subjected to a set of constraints. The central concept is that of the viability kernel, a set of initial states from which there is a remaining evolution in the set of constraints.

1.1 Viability theory

✓ Controlled dynamic systems and viability kernel

- Controlled dynamic system

The viability model in the general form of a controlled dynamic system is as follows:

$$\forall t \geq 0 \quad (S) \begin{cases} x'(t) = f(x(t), u(t)) \\ u(t) \in U\big(x(t)\big) \\ x(t) \in K \end{cases} \qquad \text{with} \quad x'(t) = \frac{dx(t)}{dt} = f(x(t), u(t))$$

$x(t)$: represents the state variable.

$u(t)$: The control variables, belong to an admissible set that depends on the state variables $U\big(x(t)\big)$ all $t \geq 0$.

K : represents the set of constraints on the state of the system which must be respected for all $t \geq 0$.

$x'(t)$: It is the dynamics of the system that directs the evolution of the state variables under the action of the controls.

For a dynamical system defined by the system (S) and a set of time-independent constraints K, there is no reason why, starting from a point $x(0) = x_0$, there should be a solution of (S) that always remains in K or at least until an instant T. We are then

interested in the viable solutions of the system (S), i.e., the solutions that never violate the imposed constraints, i.e., that always remain in K.
A function $x(.)$ is said to be viable in K if for all $0 \leq t \leq T$, $x(t)$ belongs to K.

1.2 Viability kernel

The largest subset of initial values of K from which at least one viable solution is derived, i.e., a solution that never leaves K or a solution that does not leave K until a time greater than T is called the viability kernel. And is denoted $Viab_f(K)$.
The viability of kernel makes it possible to distinguish between viable and non-viable developments. What to do with this information in the case of a non-viable situation? The first question that comes to mind is to ask how long it will take for the constraints to be violated. To answer this question, we will use the exit time function. In the case of a non-viable evolution, viability can be restored afterwards. The crisis time function allows to evaluate the time that an evolution spends outside the set of constraints.
The kernel of viability of this system is the set:
$Viab_f(K) \coloneqq \{x_0 \in K \; such \; that \; \exists u(.) \; and \; \exists x(.) \; solution \; of \; system \; with \; x(0) = x_0\}$,
i.e., for all $x_0 \in K$, there exists a viable solution of the system (S) in K with the initial condition $x(0) = x_0$.

1.3 The tools of viability theory

The distinction between viable and non-viable evolutions is possible thanks to the viability kernel. In the case of non-viable evolution, the question that can be asked is: for how long will the constraints be violated? To answer this question, we use the output time function. In case of non-viable evolution, viability can be restored later. The crisis time function allows to evaluate the time that an evolution spends outside the set of constraints. In the following paragraphs we will return to the maximum exit time function and the minimum crisis time function.

✓ Maximum output time function

When starting from a state belonging to a constraint set and not to the viability kernel, all finite time evolutions leave the constraint set. The output time function measures the time taken to satisfy the constraints. The maximum output time function associates to a state of the system the set of evolutions coming from this point. Its value is null outside the system, finite in the set of constraints, but outside the viability kernel and infinite in the viability kernel. The maximum output time function allows us to determine the maximum time that an evolution can take to satisfy the constraints with the adapted control functions for a state in the set of constraints, but outside the viability kernel. The importance of this information lies in the simple fact that it allows us to find the number of times we have to find new possible controls to ensure the viability of the system.

✓ Minimum crisis time function

The viability kernel allows us to communicate an initial information on the distinction between viable and non-viable situations. We are interested in the case of non-viable situations. An evolution is said to be non-viable if it does not respect the constraints for at least a given period of time. It can sometimes happen that an evolution does not satisfy these constraints during a given time T before returning inside the set of constraints. We speak in this kind of case of viable evolutions for the constraint set K at scale T. This is mathematically translated as: $\mu(t \setminus x(t) \notin K) \leq T$. With μ the Lebesgue measure. The notion of viable at time T includes the notion of viable for T = 0.

The crisis time function measures the time that an evolution spends outside the constraint set. When the evolution is viable, the crisis time is zero. The crisis time is finite when the evolution leaves K before returning to the viability kernel and staying there. On the other hand, the crisis time is infinite when an evolution leaves K and never returns.

The minimum crisis time function defined on the set of states takes the minimum crisis time on all the evolutions coming from this state. When the state belongs to the viability kernel, the value of the minimal crisis time is null, otherwise the value of minimal crisis time is strictly positive.

✓ Calculation of the viability kernel

The viability kernel is a very important element of viability theory. As previously defined, the viability kernel is the set of all initial situations from which there exists at least one viable evolution. Its calculation is a difficult task. It should be noted in the literature that very few exact viability kernels have been calculated. Aubin (1991) calculated an exact viability kernel in the case of a simple economic model.

In the following paragraphs, we will present the two-dimensional (Abrams-Strogatz model) and three-dimensional (Minett-Wang model) models.

✓ Abrams-Strogatz model

We are in a two-dimensional model in which we will calculate the theoretical boundaries of the viability kernel. It is indeed the Abrams-Strogatz model.

Abrams, (2003), studies a population in which two languages are competing. The objective of this study is to know the evolution of the proportions of people who speak each of the languages and to determine if it is possible that these two languages can coexist or if one of the two languages will eventually disappear. The author assumes a constant population in this study.

2. Presentation of the study framework

2.1 Model presentation

✓ State variables

ω_A : proportion of the population speaking language A, with $0 \leq \omega_A \leq 1$.

ω_B : proportion of the population speaking language B.

δ : prestige associated with language A, with $0 \leq \delta \leq 1$

$1 - \delta$: prestige associated with language B.

People who are bilingual are not considered in this model. We will ultimately retain two variables in this model, as the proportion of the population that speaks language B can be inferred from the proportion of the population that speaks language A, i.e., $\omega_B = 1 - \omega_A$.

For simplicity ω_A will be noted ω. The two variables chosen are ω and δ with:

$$\begin{cases} 0 \leq \omega \leq 1 \\ 0 \leq \delta \leq 1 \end{cases}$$

2.2 Dynamics of the model

Language A grows in size as a function of the proportion of people who speak it and the prestige associated with it. The prestige of a language varies abruptly, which is why we introduced a control variable $u \in [u_{min}; u_{max}]$ on the variation in prestige so that we could account for a slow evolution of prestige. The dynamics of the $(\omega', \delta') = F(\omega, \delta, u)$ model are as follows:

$$\omega' = F_\omega(\omega, \delta) = (1-\omega)\omega(\omega^{\alpha-1}\delta - (1-\omega)^{\alpha-1}(1-\delta))$$
$$\delta' = u \quad ; u \,\epsilon [u_{min}, u_{max}]$$

with a fixed parameter.

✓ Constraints

Recall that the goal here is the coexistence of the two languages. In order to avoid that these two languages disappear we added a new constraint on the proportion of people who speak language A: $\delta_{min} \leq \delta \leq \delta_{max}$. Regarding the prestige associated with language A, we did not add any new constraint. The set of constraints K is thus defined as follows:

$$K = \{(\omega, \delta) \ / \ \omega_{min} \leq \omega \leq \omega_{max} \ \ et \ \ 0 \leq \delta \leq 1\} = [\omega_{min}, \omega_{max}] \times [0,1]$$

✓ Viability kernel

We are looking for the set of initial situations (in terms of the proportion of people who speak language A and associated prestige), such that with the adapted prestige evolutions, the two languages can coexist. We are looking for the viability kernel of F under the set of constraints K, denoted $Viab_F(K)$.

2.3 The Minett-Wang model

The model presented above does not take into account dual language speakers, i.e., bilinguals who speak languages A and B. Minett & Wang, (2008) tried to take bilinguals into account in their study, which led them to an Abrams-Strogatz model extension. From a two-dimensional model, we move to a three-dimensional model.

The variables considered in this three-dimensional model; the Minett-Wang model are:

ω_A : proportion of people who speak only language A.

ω_B: proportion of people who speak only language B.

δ: prestige associated with language A.

1- δ: prestige associated with language B.

As mentioned above this model takes into account the proportion of people who speak both languages A and B.

$1-\omega_A-\omega_B$: the proportion of bilingual people.

So, we have: $\begin{cases} 0 \le \omega_A \le 1 \\ 0 \le \omega_B \le 1 \\ 0 \le \delta \le 1 \end{cases}$

✓ Dynamics of the model

Given a slow variation in prestige, we introduce a control variable u between – u et u. The dynamics $(\omega'_A, \omega'_B, \delta') = F(\omega_A, \omega_B, \delta, u)$ are defined as follows:

$$\begin{cases} \omega'_A = (1-\omega_A-\omega_B)(1-\omega_B)^\alpha \delta - \omega_A \omega_B^\alpha (1-\delta) \\ \omega'_B = (1-\omega_A-\omega_B)(1-\omega_A)^\alpha (1-\delta) - \omega_B \omega_A^\alpha \delta \\ \delta' \in [-u,u] \quad u \in \mathbb{R} \end{cases}$$ with a fixed parameter.

The objective of this model is to answer the following question: Is it possible to maintain a proportion of people who speak only one of the two languages?

The set of constraints K is defined as follows:

$K = \{(\omega_A, \omega_B, \delta) \in [\omega_{A,min}; 1] \times [\omega_{B,min}; 1] \times [0;1]; \omega_A + \omega_B \le 1\}$

✓ Viability kernel

It will be necessary to determine the viability kernel, i.e., the set of initial situations in terms of speakers of language A, language B and associated prestiges, for which there can be coexistence of speakers of each of the two languages with the evolution of the adapted prestiges. This set constitutes the viability kernel of F subject to the set of constraints K.

Faced with the very long computation time, the use of very large memory space and the complexity of the proofs for the exact boundaries of the viability kernel for dimensions four and five, algorithms for approximating a viability kernel have been developed. You will find a presentation of his algorithms in the article of Saint Pierre, (1994). We will not present these algorithms since our study is limited to a three-dimensional model.

3. Application of the theory of sustainability to the case of health insurance in Côte d'Ivoire.

This section is devoted to illustrating the concepts developed above. In this work, we are interested in the sustainable management of a compulsory social health insurance system. The objective here is to determine the policy actions that will ensure the sustainability of the insurance system by guaranteeing a minimum of health care to the population without impoverishing it. The tools of sustainability theory are suitable for studying this case of sustainable management. These tools provide a set of strategies to satisfy our economic and health constraints.

3.1 Modelling the viability of the insurance system in Côte d'Ivoire

We propose here a sustainable management of the Ivorian insurance system by taking into account both the conservation of the financial resource and the improvement of the health capital of the population. We will look for sustainable management policies that will make it possible to satisfy these two aspects. As outlined in section 2.3, the tools of sustainability theory are particularly well suited to the study of this problem. Using the tools outlined in Section 2.2, we translate our sustainable management problem into the formalism of sustainability theory. We model the main dynamics, specify the possibilities of action and define controls. Then, the reconciliation of health (health capital and medical care) and financial or economic aspects is translated into a set of constraints. From these definitions, the sustainability problem is stated to distinguish sustainable action policies. Then, we compute the set of viable solutions thanks to the viability algorithms. Finally, the description and analysis of these results allow us to define sustainable policies that ensure the maintenance of the insurance system and the improvement of the health capital of the population. In particular, it is possible to determine the amount of monthly premiums or contributions required per individual.

3.1.1 Choice of state and control variables

✓ State variables

The dynamic model presented in this section aims to represent (describe) the Ivorian compulsory health insurance system. We are interested in the links between the conservation of the insurance system, which requires good management of financial resources, and the consumption of health care services in times of need, and even the improvement of well-being. We favour a model with a number of variables. In order to avoid long computation times and a very large memory space, we have imposed a maximum of 3 state variables to write the dynamics of the main processes.

Maintaining the compulsory health insurance system implies a health production function F that is a function of the health capital (K) and the monthly premiums or contributions (R) paid by the insured population.

The potential loss of insurance could be explained by strong growth in the consumption of health care benefits and strong population growth. For this reason, we felt it was important that population and consumption be variables in the model. The population is described by the number of individuals (P). Moreover, since variations in the population growth rate are important in modelling the Ivorian insurance system, but since we are unable to predict a future population growth rate, we opt for a constant population growth rate. Finally, the management of health

insurance that interests us is a management that does not only consider the health insurance system, but also includes socio-economic aspects. This is why we will take into account the health capital (K) common to this population in order to be able to report on the level of health of the population.
In addition to this financial resource (collection of policyholders' contributions), the insurance system starts with a health capital K_0. We assume a positive rate of depreciation of health capital β, which decreases with increasing age of individuals.
Providing care benefits to individuals increases well-being but results in a negative change in the financial resource of the insurance.
We want to produce health care and enable individuals to get health care at a lower cost through mandatory health insurance services.

3.1.2 Control variables

We have chosen a number of controls that allow us to act on the model. We seek to define economically viable policies here. To do so, we have determined a certain number of means at our disposal.
Consumption (C) of health care benefits, the growth rate of per capita consumption, and the resource extraction flow are control variables.

3.1.3 Dynamics of the model

Investing in health capital leads to improved health status:
$\dot{K} = F(K_t, R_t) - C_t - \beta K_t$
Capital varies with consumption (C) of care benefits, output $F(K_t, R_t)$), and the rate of depreciation (β) of capital.
The insurance system is endowed with an exhaustible and renewable financial resource (S) that is continuously reduced by the flow R_t ($R \geq 0$) of benefit costs borne by insurance: $\dot{S} = -R_t$.
The population change: $\dot{P} = nP$, increases with the population growth rate of the population.
The change in consumption: $\dot{C} = (v_t + n)C_t$, increases with n and v respectively the population growth rate and the growth rate of consumption of insurance care benefits.
The model studied is a dynamic model controlled under constraints.

3.1.3.1 Constraints

The challenge of this modelling work is to determine the policy actions that will ensure both the safeguarding of the insurance system and the maintenance of the population's level of health. In order to satisfy this dual health and economic objective, we define the following constraints:

✓ Constraints on health capital

The goal is to ensure a minimum level of health for the population. We have translated this objective into two constraints on health capital. First, we assume a strictly positive health capital per capita. Thus, the first economic constraint is: $k > 0$. Then, in a second step, we add a stronger constraint by requiring that the health capital per capita decreases with increasing age. This means that the current level of health must not only be maintained but must increase from year to year until it reaches a threshold and then decrease.

✓ Constraint on the provision of insurance services or benefits (or consumption of care benefits).

The objective is to ensure good health to individuals living in the territory of Côte d'Ivoire. We translate this constraint on health by the provision of minimum fixed care C_{min} to be provided to the population. In addition, the consumption of care must not exceed the capacity of the insurance: $C_{min} \leq C(t) \leq K_t^{\alpha} R_t^{1-\alpha}$. The growth rate of consumption can be higher than a minimum consumption threshold: $v \geq v_{min}$.

✓ Constraint on resource extraction

The amount of the financial resource extraction flow must not exceed a maximum threshold: $R_{min} \leq R \leq R_{max}$.

The sustainability constraints considered are the preservation of a minimum stock of financial resources of the insurance and a minimum threshold of (insurance assumption) consumption (c_0) for each population level or generation. Thus, intergenerational equity will be ensured.

The objective of this work is to determine whether there are control functions, extraction flows and consumption, that allow the satisfaction of the sustainability constraints. The tools of the viability theory, in particular the viability kernel, will become indicators of the sustainability of our insurance system. Indeed, if they obtained kernel is empty, it means that the current model does not allow to achieve the objectives, this economic model can then be qualified as unsustainable. Equity is the absence of avoidable or remediable differences between different groups of people, whether they are defined according to social, economic, demographic, or geographic criteria (WHO, 2020).

3.1.3.2 Model formulations and parameters

✓ Formulation of the model

The state representative of the social insurer is a continuity, that is, the benefits and services of the insurance can be perpetuated and / or improved over time. The objective of the State is to ensure good health for its population in a spirit of intergenerational equity. Thus, the social insurer (State) will seek to maximize the following equity criterion:

$$\underbrace{MAX}_{C\ ,\ R} \int_0^{+\infty} U(C_t)e^{-\rho t}\, dt \qquad with\ U(C_t) = \begin{cases} \dfrac{C^{1-\theta}-1}{1-\theta} & si\ \theta > 0, \theta \neq 1 \\ \ln(C) & si\ \theta = 1 \end{cases}$$

Under the constraint of the dynamics:

$$\begin{cases} \dot{K} = F(K_t, R_t) - C_t - \beta K_t \\ \dot{S} = -R_t \\ \dot{P} = nP \\ \dot{C} = (v_t + n)C_t \end{cases}$$

For the purpose of simplifying the analysis, we use the per capita variables:

$k = \frac{K}{P}$: health capital per insured individual

$s = \frac{S}{P}$: the annual cost of care per insured individual

$c = \frac{C}{P}$: the consumption of health care benefits per individual

$r = \frac{R}{P}$: the annual premium paid per insured individual

For reasons of simplification, the units of efficiency are the accumulation of health capital, the process of resource extraction, the increase in population and the increase in consumption. The dynamics can be reformulated as follows:

$$\begin{cases} \dot{k} = k^{\alpha} r^{1-\alpha} - (n+\beta)k_t - c_t \\ \dot{s} = -r_t - ns_t \\ \dot{p} = nP_t \\ \dot{c} = v_t c_t \end{cases}$$

And the constraints of limits and non-negativity:

$k(0) = k_0,\ \ k(t) \geq 0$

$S(0) = S_0,\ \ S(t) \geq 0$

Relationship characterizing the constraints on the state variables (k, s, c) and control variables $(r, n\ and\ v)$:

$$\begin{cases} k \geq 0 \\ s_0 \leq s \leq s_{max} \\ c_0 \leq c \leq k^{\alpha} r^{1-\alpha} \\ r_{min} \leq r \leq r_{max} \\ v \geq v_{min} \\ n = 2{,}6 \end{cases}$$

With:

s_0 : the minimum annual cost of coverage per insured individual.

s_{max} : the maximum annual cost of coverage per insured individual.

c_0 : minimum consumption threshold per insured individual guaranteed for all generations.

Constraint (3) is an accounting constraint; it relates to the total consumption of health care benefits, which cannot exceed the basket of care produced or insured by the social insurer.

The financial resource of the insurance can decrease if the amount of coverage per insured individual, the population growth or/and the consumption per individual are too high. In our analysis, we have assumed a constant population growth rate. Thus, the social insurer's financial resource per individual may decrease if the amount of the extraction flow from the insurer's financial resource or the consumption of health care benefits per individual is too high.

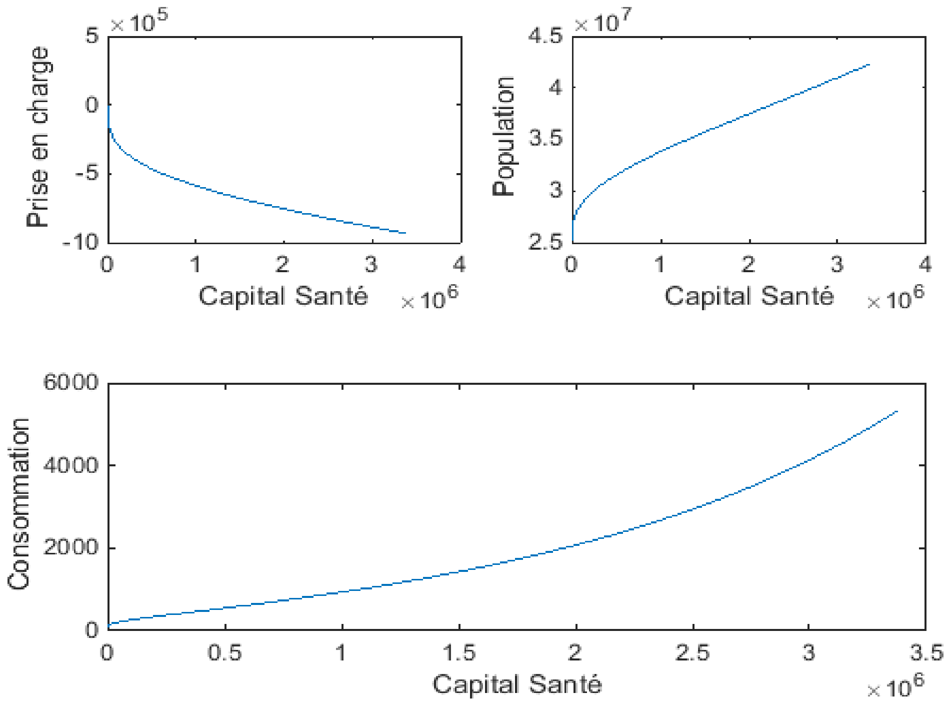
✓ The parameters of the model

The purpose of studying this model is not to reproduce reality or predict the future, but to explore possible scenarios and illustrate how the tools of sustainability theory can be used in a sustainable health insurance system problem. Some of the parameter values described in the table below are taken from the literature and from the WHO (2020) database.

Definitions	Notations	Units	Values
Elasticity of substitution	α	No units/year	3/4
Rate of depreciation of health capital	β	No units/year	1/4
Population growth rate	n	Without unit/year	0.026
Maximum withdrawal amount	r_{max}	Fcfa/capita/year	100,000
Minimum withdrawal amount	r_{min}	Fcfa/capita/year	60,000
Minimum consumption threshold	c_0	Fcfa/capita	70
Minimum cost of care	s_0	Fcfa/capita/an	0.7
Maximum cost of care	s_{max}	Fcfa/capita/an	100,000
Minimum Incremental Rate	v_{min}	Without unit/year	0.2
Initial health benefit	k_0	Fcfa/capita	56.6
Initial population	P_0	Capita	25,195,140

Table of parameter values, control bounds and model constraints.

The evolution of the level of consumption per insured individual is determined by the dynamic $\frac{dc}{dt} = v_t c_t$. Inequalities between populations should be reduced by establishing a form of equity between them through the respect of constraints. In this study, the growth rate of consumption per insured individual v_t, is constrained to be always greater than or equal to a certain minimum threshold v_{min} ($v_t \geq v_{min}$). From an initial situation belonging to the core, we have the possibility to find a viable and equitable social insurance path provided that the core is not empty. The growth rate of consumption v_t per insured individual of any population can be made to decrease; but this decrease must respect the constraint $v_t \geq v_{min}$. This constraint added to the other constraints prohibits behaviours of insured individuals that could negatively impact future consumption. For a zero v_{min} the future consumption per insured individual could not be below the previous consumptions. A negative v_min would imply that the consumption per insured individual would decrease without being below an acceptable threshold. However, a positive v_{min}, would imply that the consumption per insured individual would increase exponentially with the future population level. Therefore, if all the constraints are not met, the viability kernel will be empty. We did not find it important to increase the growth of future consumption by an a priori constraint other than those on production capacity. The evolution of the consumption level per insured individual is constrained by: $v \geq v_{min}$. A moral



duty of the current population to their offspring.

3.2 Results of the study

Figure 1: link between state and control variables

We see a decrease in care when the population increases. This result can be explained by the fact that with a large population, the cost of care becomes unbearable for the State of Côte d'Ivoire. This increase in population leads to an increase in consumption. The increase of the consumption resulting from the assumption of responsibility becomes an unbearable cost for the State. The State will therefore proceed to reduce the cost of care, or even eliminate it. We then return to the previous situation.

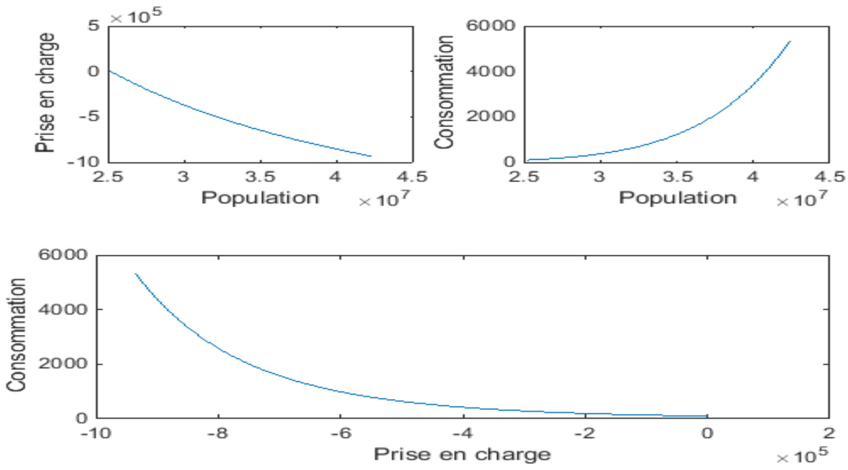
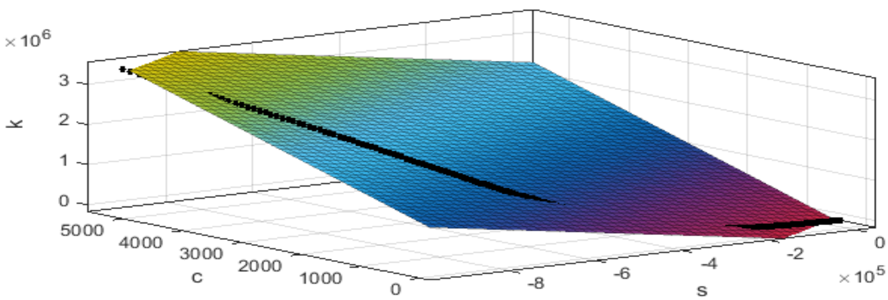


Figure 2: link between state and control variables

An increase in the population leads to an increase in negative care and therefore an absence of positive care, or even an absence of insurance from the State of Côte d'Ivoire. An increase in the population leads to an increase in consumption. And an improvement of the negative assumption of responsibility, or even null, leads to a decrease in consumption.



Estimation result (simulation)

Data	Fit type	SSE	R-square	DFE	Adj R-sq	RMSE	# Coeff
K vs s, c with…	Poly11	1.1718e+20	0.9851	198	0.9851	7.6930e+08	3

Figure 3 presents the viability core of the study model. The kernel of viability contains the set of initial situations from which there is an evolution that respects both the constraints of the defined model and the defined form of equity between generations. The trajectory of the system provided by figure 3 is not viable. This is because the evolution of the trajectory of the system does not remain definitively in the core of viability. We deduce that our insurance system is therefore not sustainable.

5 Conclusion

This article aims to analyse the sustainability of universal health coverage in Côte d'Ivoire in the face of the question of whether the policy or Universal Health Coverage adopted by the state of Côte d'Ivoire is sustainable. The answer to this question was possible through the use of mathematical sustainability theory and its application to the health insurance system. The theory of sustainability allows for the integration of the main characteristics of a sustainable insurance system. This study shows that the universal health coverage system is not sustainable. It is therefore impossible for the system to generate sufficient and sustainable resources to ensure access to health care for all. It should be noted that this critical study aims to help decision-makers rethink policies for the implementation of universal health coverage (UHC). As a recommendation, we ask decision-makers to rethink the financing of the health insurance system and to control the rate of population growth to avoid falling into the Sisyphus syndrome, because rapid population growth requires additional resources.

Références

Berghmans, L. (2009). Inégalités sociales de santé, une histoire ancienne d'actualité. *Éducation Santé, 245*, 3-4.
Bicaba, A. J., & al. (2003). Accès aux urgences chirurgicales et équité. *Ouagadougou, ABSP, CRDI, Université de Montréal*.
De Koninck, M. R., & al. (2008). *Santé : pourquoi ne sommes-nous pas égaux ? Comment les inégalités sociales de santé se créent et se perpétuent*. Québec: Institut national de santé publique du Québec.
Diallo, I. F., & Sarr, A. (1997). . *l'Initiative de Bamako au Sénégal. In J. Brunnet-Jailly (Ed.), Innover dans les systèmes de santé, Expérience d'Afrique de l'Ouest (pp. 209-218.).* Paris, France: Editions Karthala. .
Gilson, L. (2000). impacts sur l'équité des activités de financement communautaire dans trois pays africains. *Journal international de planification et de gestion de la santé.*, 291-317.
Jaffré, Y., & Sardan, J.-P. O. (2000). Une médecine inhospitalière. Les relations entre soignants et soignés dans cinq capitales d'Afrique de l'Ouest. *OpenEdition*, 449.

Meunier, A. (1999). *Le système de soins au Burkina Faso. Le paradoxe sanitaire.* Paris: Karthala.
Ndiaye, S. (2012). Analyse des performances des districts sanitaires de Nongr-Massom (Burkina Faso) et de Touba (Sénégal) face à l'endémie du paludisme. *thèse de doctorat de sociologie, Université Gaston Berger*.
Ndiaye, S. (2017). Le fonds d'équité au Sénégal : analyse des mécanismes de la couverture maladie des indigents et de ses perspectives pour la couverture maladie universelle. *Afrique et développement, XLII*, 9-31.
Potvin, L. M.-J., & Jones, C. (2010). *Réduire les inégalités sociales en santé.* Saint-Denis: INPES, Santé en action.
Ridde. (2008). Equity and health policy in Africa: Using concept mapping in Moore (Burkina Faso). *BMC Health Services Research*.
Ridde, V. (2004). L'initiative de Bamako 15 après Un agenda inachevé. *Health, Nutrition and Population (HNP) Discussion Paper*.
Salomez, J.-L. (2010). Inégalités sociales de santé : une longue histoire. *Contact santé n° 231*.
Standing, H. (2002). Un aperçu de l'évolution des agendas dans les réformes du secteur de la santé. Questions de santé reproductive. 19-28.
Sy, F. (1999). *La consommation de médicaments et les circuits thérapeutiques à Dakar.* (S. e. J. Brunnet-Jailly (Éd.), Éd.) Abidjan,: CEDA.