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ACTUARIAL ANALYSIS OF A TWO-STEPS DECUMULATION PENSION SYSTEM

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Abstract

The problems of the different pension systems motivated by longevity and exacerbated by the economic crisis mean that all countries are undertaking certain reforms in order to try to solve them. These reforms are made on two forms, either parametric or structural. The parametric ones suppose that the system parameters are modified, such as the age of retirement or the formula to calculate the pensions, for example. The structural reforms involve changes in the chosen system, moving from the pay-as-you-go system to the capitalization system, as an example. In this paper we propose a different system, which does not imply the modification of any parameter nor does it imply structurally changing the system. We explore the idea of modifying the way in which benefits are perceived. In all the pension systems currently applied, the pension collected during retirement is composed of two amounts: the one generated by social security with the pay-as-you-go system, and at the same time, the one obtained with the private system. The basic idea of the model we propose, called two-steps mixed system, instead of an horizontal superposition of the two pillars after retirement age, proposes to decumulate in two phases. In our two-steps mixed system, when workers reach their ordinary retirement age they receive a 'term annuity' generated by their previous capitalized savings to be replaced by a Social Security defined contribution 'pure life annuity' when the so-called 'grand age' is reached.

We have worked with this idea in other papers (Herce et al. (2013), Domínguez et al. (2018), Devolder et al. (2018a, 2018B)), and now in this one we generalize the simple two period model presented in our previous paper and consider a very general multi age actuarial model. For further progress in the design and development of Two step system board we give also new results on the way to define the grand age based on two possible ways to define continuity of the model .

Keywords: *individual analysis, grand age, two-steps mixed system, term annuity,*
JEL codes: *G00; G22; G29*

1. Introduction

There is a large consensus in the pension literature (and in the existing structure in many countries), to promote a pension pillar approach based on the superposition of a first pillar in pay-as-you-go (social security) and a second pillar fully funded (occupational pensions). Indeed the advantage of this architecture is to diversify the demographic risks implicit to a pay-as-you-go system with the financial risks induced by a fully funded scheme. Nevertheless, this classical approach can lead to inefficacies due to adverse selections and friction costs in the funded pillar. We suppose that the funded scheme is decumulated as the first pillar under the form of lifetime annuities. If a private institution (for instance an insurer) pays these funded annuities, we know then that the long-term aspect of the product will generate friction costs for the pricing of the annuity. In particular, the insurer will ask management cost (sometimes very expensive) and will apply a prudential life table by distorting the survival probabilities (Blake et at. (2008), Finkelstein and Poterba (2004), Mitcheel et al (1999), Morales and Larraín (2017) and Whitehouse and Zaidi (20018)) In some cases he will even refuse to sell this kind of product taking into account the long term uncertainty of longevity and the important capital requirement as asked for instance by Solvency II. Therefore, while keeping for diversification purposes, coexistence of pay-as-you-go and fully funding, it could be useful to change the decumulation strategy of the two pillars. The two-steps methods as introduced in Herce et al. (2013), Domínguez et al. (2018), Devolder et al. (2018a, 2018B) proposes to solve this problem. Instead of an horizontal superposition of the two pillars after retirement age, this approach proposes to decumulate in a first phase the totality of the funded capital, under the form of a term annuity between retirement age (for instance 65 years old, the same age as in the classical system) and another age called grand age (for instance 75 years old). The social security pay-as-you-go pillar starts then after this grand age (vertical superposition of pillars instead of the horizontal one).

This alternative decumulation strategy avoids the use of funded lifetime annuities, which in practice are expensive, and help the financial sustainability of the social security by deferring the payment of pension from retirement age to grand age. In this paper, we develop an actuarial model in order to access this two steps methodology and to compare it with the classical decumulation strategy. The paper is structured as follows. The next section presents the main assumptions and develop the classical decumulation approach. In section 3, we present the actuarial computation of the two-steps method on a multi period model in a deterministic framework. Section 4 compares the two decumulation strategies in terms of internal rates of return for the affiliated (IRR). In section 5, we introduce some something conditions that can help to estimate a proper grand age. The paper is finished with the conclusions obtained and the future research proposal about the two step system.

2. Assumptions and classical decumulation

2.1. General architecture

We consider a pension structure based on two pillars:

- A first pillar in pay-as-you-go organized by the social security and using a notional mechanism (NDC) ;
- A second pillar sponsored by employers (or other professional groups) and based on a fully funded DC scheme.

We assume that everybody has access to these two pillars on a similar way (compulsory schemes).

2.2. First pillar: the NDC scheme

We assume that contributions based on a fixed contribution rate are paid during the whole career and are virtually accumulated in a notional account (PAYG system).The returns associated with this notional account are computed using notional rates. At retirement age, we obtain a notional capital that has to be virtually transformed into a pension. We will use the following notations:

$$\pi_N = \text{contribution rate (in NDC)}$$
$$x_r = \text{retirement age}$$
$$C_N = \text{notional capital at retirement age}$$

We are mainly interested here in the decumulation phase after retirement; therefore, we will work directly with the notional capital C_N. This capital is generated by the contributions paid during the accumulation phase and can be written as:

$$C_N = \sum_{x=x_0}^{x_r-1} \pi_N.S(x).\left(\prod_{y=x}^{x_r-1}(1+r_y)\right) \tag{2.1}$$

where:

$S(x) =$ salary at age x

$r_y =$ notional rate applied between age y and y+1

$x_0 =$ entry age

For instance, if we use constant rates of increase of the salary and constant notional rates throughout the career, we get explicitly:

$$C_N = \pi_N.S(x_r-1).(1+r).\frac{1-\left(\frac{1+r}{(1+\beta).(1+k)}\right)^n}{1-\left(\frac{1+r}{(1+\beta).(1+k)}\right)} \tag{2.2}$$

where:

$n = x_r - x_0 =$ duration of the career

$\beta =$ inflation rate

$r =$ notional rate

$k =$ yearly increase of salary related to age

At retirement age, the virtual capital C_N given by (2.1) is converted into an initial pension denoted by P_N; afterwards, we assume that the pension increase each year at the rate β. In the classical NDC decumulation process, this conversion is based on an immediate lifetime annuity (pension to be paid from retirement age until death):

$$P_N = \frac{C_N}{\ddot{a}_{x_r}^N} \tag{2.3}$$

with: $$\ddot{a}^{N}_{x_r} = \sum_{x=x_r}^{\omega} \left(\frac{1+\beta}{1+r}\right)^{x-x_r} {}_{x-x_r}p_{x_r} \tag{2.4}$$

where:

$${}_{x-x_r}p_{x_r} = \text{probability to survive at age x being alive at age } x_r$$

$$\omega = \text{last age}$$

2.3. Second pillar: the fully funded scheme

In the classical model, the contributions accumulated in the DC fully funded scheme are also converted in a life time annuity at retirement age. At retirement age, the funded capital becomes:

$$C_F = \sum_{x=x_0}^{x_r-1} \pi_F.S(x).\left(\prod_{y=x}^{x_r-1}(1+i_y)\right) \tag{2.5}$$

where:

$$\pi_F = \text{contribution rate (in funding)}$$

$$C_F = \text{funded capital at retirement age}$$

$$i_y = \text{financial return between age y and age y+1}$$

If we use constant rates of increase of the salary and constant financial returns, we get explicitly:

$$C_F = \pi_F.S(x_r-1).(1+i).\frac{1-\left(\frac{1+i}{(1+\beta).(1+k)}\right)^n}{1-\left(\frac{1+i}{(1+\beta).(1+k)}\right)} \tag{2.6}$$

The funded pension at retirement age is computed in a same way as in the NDC but with two important differences. We assume that a private annuity provider (typically an insurance company) pays this part. Therefore, friction costs will appear under two forms:

- management cost for the payment of the benefits
- use of a prudential life table for the survival probabilities (important risk aversion of the insurer with respect to a lifetime product and adverse selection).

The initial pension for the funded part becomes then:

$$P_F = \frac{C_F}{\ddot{a}^F_{x_r}} \tag{2.7}$$

with: $$\ddot{a}^F_{x_r} * = \frac{1}{1-g}\sum_{x=x_r}^{\omega}\left(\frac{1+\beta}{1+i}\right)^{x-x_r} {}_{x-x_r}p*_{x_r} \tag{2.8}$$

where:

$$\begin{aligned} {}_{x-x_r}p*_{x_r} &= \text{adapted probability to survive at age x} \\ g &= \text{management cost of the annuity provider} \\ i &= \text{discount rate} \end{aligned} \tag{2.9}$$

A way for the insurer to adapt the life table for lifetime annuity is to change the age of the annuitant by reducing its age by a fixed quantity (for instance 5 years younger). If we denote by m this number of years used in the correction, we get:

$$\begin{aligned} {}_{x-x_r}p*_{x_r} &= {}_{x-x_r}p_{x_r-m} \\ m &= \text{number of years for the correction} \end{aligned} \tag{2.10}$$

This kind of age correction for annuities is for instance used explicitly in the regulation of life insurance in Belgium.

2.3. Total pension revenues in the classical model

In this classical decumulation process, the total pension received from the two pillars at any age x after retirement and denoted by $P^{(1)}_x$ is just given by the sum of the two pillars:

$$\begin{aligned} P^{(1)}_x &= \text{pension at age x} = \left(P_N + P_F\right).(1+\beta)^{x-x_r} \\ &= \left(\frac{C_N}{\ddot{a}^N_{x_r}} + \frac{C_F}{\ddot{a}^F_{x_r} *}\right).(1+\beta)^{x-x_r} \qquad (x \geq x_r) \end{aligned} \tag{2.11}$$

The sign * in the second annuity refers to the presence of mortality adjustment and management cost.

3. New Two-steps decumulation

In order to avoid the friction costs of a lifetime annuity for the funded part, we assume now two stages in the decumulation process and a temporal different treatment between the two pillars:
a) the *funded capital* is converted at retirement age into a term annuity starting at retirement age and finishing at a chosen age called grand age (for instance a term annuity between 65 and 75).
b) the *notional capital* is converted into a deferred annuity starting precisely at grand age (for instance after 75) until death .
This new decumulation strategy has two positive consequences:
- adequacy if the benefits: it reduces or even avoids the mortality correction of a funded lifetime annuity, taking into account the shorter risk horizon of the insurer;
- financial sustainability: it delays the payment to be done by the social security.

3.1. Second pillar: the term annuity

At retirement age, the funded capital C_F given by (2.5) is now converted into a term increasing annuity with initial level denoted by $\tilde{P}_F$; this pension is increasing each year at the rate β and is paid between retirement age x_r and grand age x_G :

$$\tilde{P}_F = \frac{C_F}{\ddot{a}^F_{x_r,\overline{x_G-x_r}|}} \tag{3.1}$$

where:

$$\ddot{a}^F_{x_r,\overline{x_G-x_r}|} = \frac{1}{1-g}\sum_{x=x_r}^{x_G-1}\left(\frac{1+\beta}{1+i}\right)^{x-x_r} {}_{x-x_r}p_{x_r} \tag{3.2}$$

This time, we have deliberately omitted to adjust the survival probabilities, considering as negligible the adverse selection effect for short horizon term annuities (as opposed to long term lifetime annuities). Alternatively we could have introduced a correction but significantly lower than in the lifetime case (for instance a lower age correction).

3.2. *First pillar: the deferred annuity*

The notional capital available at retirement age is not immediately converted but has first to be deferred until grand age. Then, at grand age, it is converted into a lifetime annuity until death.
The deferred notional capital is computed at grand age, starting from the notional capital C_N (2.1) and taking into account the credit under the

notional rates and the mortality credit between retirement age and grand age. Indeed, we assume no survivor benefit for people dying before grand age, the whole notional capital of the affiliates died between retirement age and grand age going then to the survivors at grand age. This notional capital is therefore given by:

$$C_N(x_G) = \frac{C_N}{{}_{x_G - x_r}p_{x_r}} . \prod_{y=x_r}^{x_G-1} (1+r_y) \tag{3.3}$$

For constant notional rates equal to r, we get:

$$C_N(x_G) = \frac{C_N}{{}_{x_G - x_r}p_{x_r}} .(1+r)^{x_G - x_r} \tag{3.4}$$

This notional capital is then transformed at grand age into an increasing lifetime annuity, with initial level given by:

$$\tilde{P}_N = \frac{C_N(x_G)}{\ddot{a}^N_{x_G}} \tag{3.5}$$

where: $$\ddot{a}^N_{x_G} = \sum_{x=x_G}^{\omega} \left(\frac{1+\beta}{1+r}\right)^{x-x_G} {}_{x-x_G}p_{x_G} \tag{3.6}$$

3.3. *Total pension revenues in the two-steps model*

In this two-steps decumulation process, the total pension received from the two pillars at any age x after retirement and denoted by $P^{(2)}_x$ is given by:

First step (between retirement age and grand age):

$$\begin{aligned} P^{(2)}_x &= \left(\tilde{P}_F\right).(1+\beta)^{x-x_r} \\ &= \left(\frac{C_F}{\ddot{a}^F_{x_r,\overline{x_G - x_r|}}}\right).(1+\beta)^{x-x_r} \qquad (x_r \le x < x_G) \end{aligned}$$

Second step (from grand age):

$$P_x^{(2)} = \left(\tilde{P}_N\right).(1+\beta)^{x-x_G}$$
$$= \left(\frac{C_N(x_G)}{\ddot{a}_{x_G}^N}\right).(1+\beta)^{x-x_G} \qquad (x \geq x_G)$$

Table 1 summarizes the two decumulation strategies:

	Classical decumulation	***Two-steps decumulation***
Between retirement age and grand age	$P_x^{(1)} = \left(\frac{C_N}{\ddot{a}_{x_r}^N} + \frac{C_F}{\ddot{a}_{x_r}^F *}\right).(1+\beta)^{x-x_r}$	$P_x^{(2)} = \left(\frac{C_F}{\ddot{a}^F_{x_r,\overline{x_G-x_r}\rvert}}\right).(1+\beta)^{x-x_r}$
After grand age	$P_x^{(1)} = \left(\frac{C_N}{\ddot{a}_{x_r}^N} + \frac{C_F}{\ddot{a}_{x_r}^F *}\right).(1+\beta)^{x-x_r}$	$P_x^{(2)} = \left(\frac{C_N(x_G)}{\ddot{a}_{x_G}^N}\right).(1+\beta)^{x-x_G}$

TABLE 1: *comparison of the pensions in the classical and the two-steps decumulation systems*

4. Comparison between the two decumulation strategies

In order to compare the two decumulation methods from an individual point of view, we will compute here the internal rate of return at retirement age. This will measure the mean return for the affiliated in both systems.

4.1. *Definition of the two IRR*

We will define the IRR as the discount rate such that the present value at retirement age of the total pension benefits corresponds to the sum of the two capitals available at retirement age (notional and funded capitals).

a) IRR of the classical system : IRR_1 is solution of :

$$C_N + C_F = \sum_{x=x_r}^{\omega} {}_{x-x_r}p_{x_r} \left(\frac{C_N}{\ddot{a}_{x_r}^N} + \frac{C_F}{\ddot{a}_{x_r}^F *}\right).(1+\beta)^{x-x_r}.\frac{1}{(1+IRR_1)^{x-x_r}} \qquad (4.1)$$

b) IRR of the two-steps system : IRR_2 is solution of :

$$
\begin{aligned}
C_N + C_F = & \sum_{x=x_r}^{x_G-1} {}_{x-x_r}p_{x_r} \left(\frac{C_F}{\ddot{a}^F_{x_r,\overline{x_G-x_r}|}} \right).(1+\beta)^{x-x_r}.\frac{1}{(1+IRR_2)^{x-x_r}} \\
& + \sum_{x=x_G}^{\omega} {}_{x-x_r}p_{x_r} \left(\frac{C_N(x_G)}{\ddot{a}^N_{x_G}} \right).(1+\beta)^{x-x_G}.\frac{1}{(1+IRR_2)^{x-x_r}}
\end{aligned}
\qquad (4.2)
$$

4.2. *Basic case*

We will start with the basic case where there is no management cost and no mortality adjustment. Then we have the following equivalence principle:

PROPOSITION 1:

In absence of management cost and of mortality adjustment for the fully funded part, the classical and the two steps decumulation techniques will be equivalent if the discount rate used in the funded part is equal to the notional rate used in the PAYG part.

Proof:
The result is trivial: in absence of friction costs and when r = i, all the cash flows in the two decumulation approaches are discounted at a same rate which corresponds then by definition to the IRR :

$$IRR_1 = IRR_2 = i = r$$

When the notional rate of the NDC part and the discount rate of the funded part are different, this equivalence disappears even in this basic case without friction costs.

For instance, consider the following example where we consider constant notional rates and constant financial returns during the accumulation phase (formula (2.2) and (2.6) are used to obtain the two capitals at retirement age) :

- Contribution rates: $\pi_N = 15\%$ $\pi_F = 10\%$
- Notional rate: $r = 2.51\%$
- Increase of salary: $\beta = 2\%$ $k = 1\%$

- Retirement age: $x_r = 65$
- Life tables: IABE 2015 tables (Belgian life tables)

Figures 1 and 2 compares the two IRR's for different values of the grand age and of the discount rate of the funded part (value of i):

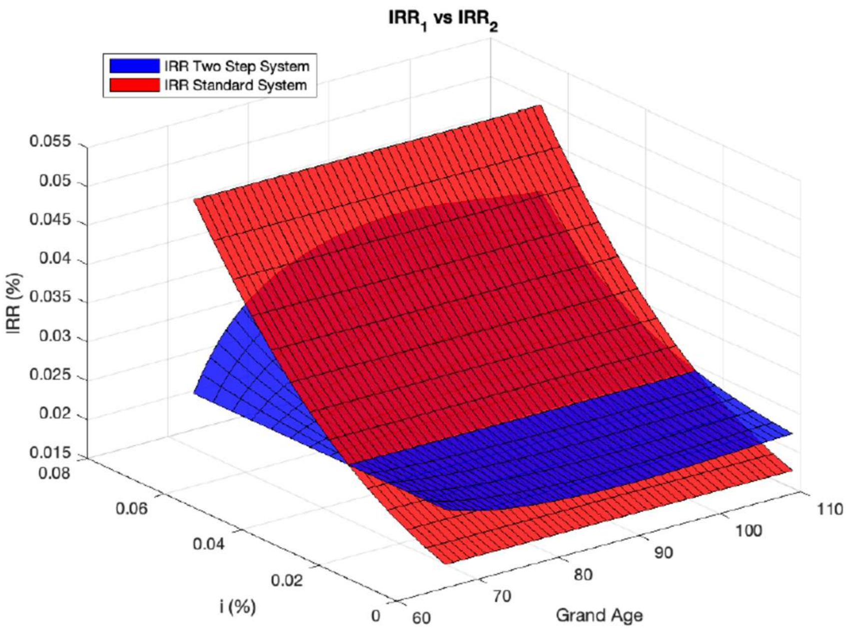

Figure 1 : *comparison between the two IRR's for different values of the grand age and of the discount rate of the funded part (no friction costs)*

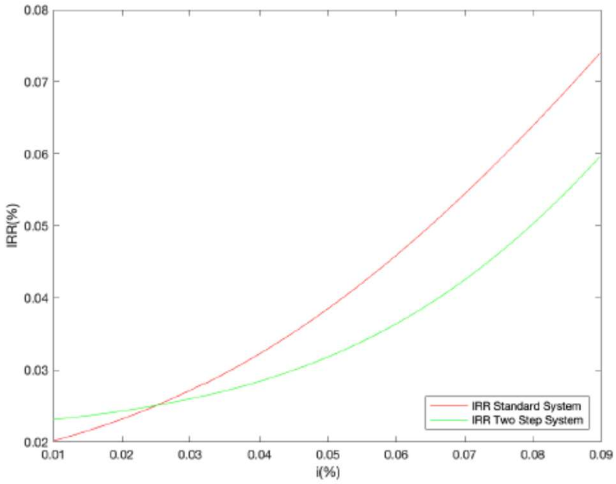

Figure 2 : *comparison between the two IRR's for different values of the discount rate of the funded part (grand age 80 ; no friction costs)*

Conclusion: as expected, we can see clearly in figure 1 that the intersection between the two surfaces corresponds exactly to a fixed value of i for any grand age (i = r = 2.51%).

The two graphs suggest that in absence of management cost and adjustment of probabilities, the two steps approach will give a better (resp. lower) IRR, if the notional rate is higher (resp. lower) than the financial return.

4.3. *General case with friction costs*

The presence of management cost (*factor g*) and mortality adjustment (*factor m*) will affect this comparison and change the conclusions of proposition 1. In fact, the presence of adjusted probabilities will decrease the IRR of the classical system for a same level of financial return i while not affecting at all the two-steps system. Therefore, the financial return of the fully funded must be much higher now than the notional rate to obtain an equivalence of IRR's between the two systems.

We illustrate this situation with the following example:

- Contribution rates: $\pi_N = 15\%$ $\pi_F = 10\%$

- Notional rate: $r = 2.51\%$
- Increase of salary: $\beta = 2\%$ $k = 1\%$
- Retirement age: $x_r = 65$
- Life tables: IABE 2015 tables
- Management cost: $g = 1.25\%$
- Adjustment of the life table: $m = 5$ years

Figures 3 and 4 compares the two IRR's for different values of the grand age and of the discount rate of the funded part (value of i):

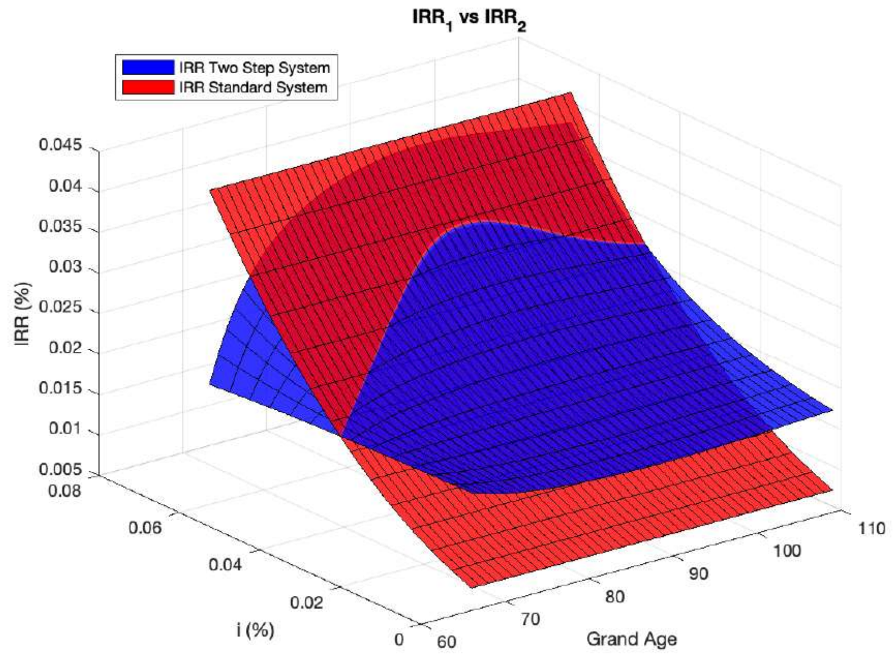

Figure 3 : *comparison between the two IRR's for different values of the grand age and of the discount rate of the funded part (with friction costs : management cost of 1.25% and age adjustment of 5 years)*

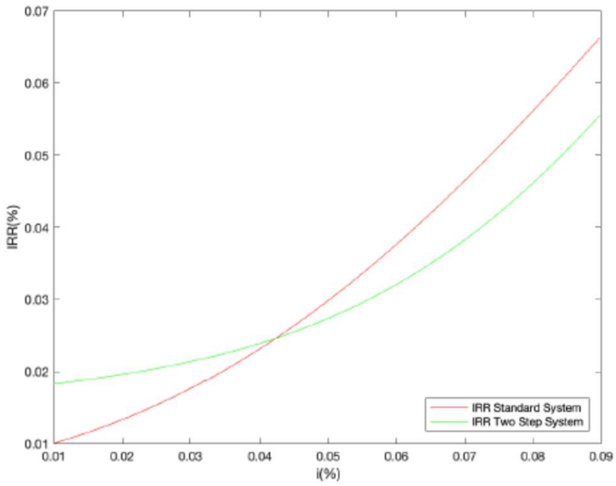

Figure 4 : *comparison between the two IRR's for different values of the discount rate of the funded part (grand age 75 ; with friction costs: management cost of 1.25% and age adjustment of 5 years)*

<u>Conclusion</u>: in presence of adjusted probabilities, the financial return giving for the classical system an equivalent IRR as the one of the two steps system is now much higher and depends now on the grand age. For instance for a grand age of 75, the classical system will be better than the two steps only if the financial return is more than 4% (to compare to the notional rate still equal to 2.51%) .

5. Choice of Grand age and continuity of benefit

The two-steps approach introduces a new parameter in the pension architecture that has to be chosen: the grand age. In order to fix this parameter, we have to look more carefully at the evolution of the benefit and their comparison with the classical system.

Indeed, the structure of the pension benefits of the two steps method is very different from the classical one. In fact, by definition, the two-steps method presents a structural discontinuity at grand age that has to be addressed (see Table 1). We could then ask additional constraints on the two-steps method in order to obey to some specific forms of continuity. This kind of constraint could help us then precisely to choose the grand age. We propose here two different possible ways to define a concept of continuity:

- Continuity of the benefits around grand age in the two steps method;

- Continuity between the classical and the two-steps method at retirement age (same initial pension at retirement age)

5.1. *Continuity at grand age*

Due the different form of the pension cash flow before and after grand age in the two steps method, there is a significant risk of discontinuity of the pension income at grand age. In order to avoid this gap, we could ask a smooth evolution of the pension at grand age. More precisely, we will ask that (exactly as in the classical model) the first pension of the second phase (paid at grand age) has to correspond in real terms to the first pension of the first phase (paid at retirement age):

$$P^{(2)}_{x_G} = P^{(2)}_{x_r}.(1+\beta)^{x_G - x_r} \tag{5.1}$$

Taking into account the values (3.1) and (3.5) of these pension cash flows, we obtain the following condition:

$$\frac{C_N}{C_F} = \frac{(1+\beta)^{x_G - x_r}}{(1+r)^{x_G - x_r}} \cdot \frac{{}_{x_G - x_r}p_{x_r}.\ddot{a}^N_{x_G}}{\ddot{a}^F_{x_r, \overline{x_G - x_r}|}} \tag{5.2}$$

This relation depends on the value of the ratio between the two capitals to decumulate. We can use this relation in two ways:

- If the grand age and the social security are fixed , relation (5.2) tells us the amount of funded capital C_F to invest in the term annuity to obtain continuity at grand age ;
- If social security and funded capitals C_N ,C_F are fixed, relation (5.2) can be seen as an implicit equation giving us how to fix the grand age x_G. This complicated equation can be solved numerically.

5.2. *Continuity at retirement age*

Another form of continuity constraint is to ask that the initial pension at retirement age should be the same in classical and two-steps. . Then between retirement age and grand age, the classical and the two steps methods will deliver the same amount of pension and the discrimination between both approaches will appear only after grand age.

The constraint becomes then:

$$P_{x_r}^{(1)} = P_{x_r}^{(2)} \qquad (5.3)$$

Using the values of the pension incomes, we get the relation:

$$\frac{C_F}{\ddot{a}^F_{x_r, \overline{x_G - x_r}|}} = \left(\frac{C_N}{\ddot{a}^N_{x_r}} + \frac{C_F}{\ddot{a}^F_{x_r} *} \right)$$

Or:

$$\frac{C_N}{C_F} = \left(\frac{1}{\ddot{a}^F_{x_r, \overline{x_G - x_r}|}} - \frac{1}{\ddot{a}^F_{x_r} *} \right) . \ddot{a}^N_{x_r} \qquad (5.4)$$

Once again, this relation could help us either to find the level of funded capital for a given grand age or the value of the grand age for a given proportion between notional and funded capitals.

6. Conclusion

In this paper, we have explored the effect of pension decumulation on the individual Internal Rate of Return applying both systems, the two-steps system and the classical system.

We have carryed out this analysis improving previous works, which dealt with just one simple two periods model and also we have considered a very general multi age actuarial model.

The main conclusion obtained when working with a multi age model is that in absence of management cost and adjustment of probabilities, the two steps approach will give a better Internal Rate of Return if the Notional Rate is higher than the Financial Return.

On the other hand, in presence of adjusted probabilities the Financial Return giving for the classical system an equivalent Internal Rate of Return as the one of the two steps system is now much higher and depends on the grand age. In the paper, the choice of the grand age amount is explored, because it is a very important parameter for the system design, and its choice will be essential if we want to avoid the risk of discontinuity of the pension income at grand age.

We conclude that the grand age can be defined, based on two possible ways to determine the continuity of the model: one of them could be made if the grand age and the Social Security amount obtained are fixed, and the other one could be made if social security and funded capitals are fixed.

To conclude, the two-steps system is an unexplored one that will require more research, but even so, after the results obtained in our work, we can affirm that it is a system that can solve many of the problems of all the agents involved in a pension system.

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