Direction des Études et Synthèses Économiques

G 2012 / 14
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Document de travail

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Série des documents de travail
de la Direction des Études et Synthèses Économiques

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Didier **BLANCHET*** - Sylvie **LE MINEZ****

19 DÉCEMBRE 2012

This work was initiated while both authors were working at Insee's Department of Economic Studies. Successive versions have been presented at the 30th IARIW conference, Portoroz, September 2008, at a D3E seminar in December 2009 and at the Netspar International Pension Workshop, Paris, June 2012. The authors thank participants to these meetings and more particularly Stijn Lefebure, Selma Mahfouz and Patrick Aubert. Opinions expressed are those of the authors and not those of Insee.

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Abstract

Accrued-to-date liabilities (ADLs) could soon add to the set of regular statistics on public pensions, in compliance with updated SNA provisions. This raises two questions: how can this indicator be produced, and what for? Microsimulation is shown to constitute a relevant answer to the first question. Despite its stochastic nature, it displays results that seem stable enough for accounting purposes. Concerning the "what for" question, it is well-known that ADLs are not an indicator of global financial sustainability. Their message is more interesting from the household perspective and especially at the micro level. This fosters the case for microsimulation that automatically produces consistent micro/macro results. All these macro and micro properties are illustrated in the French case, with applications to the assessment of the successive 1993, 2003 and 2010 reforms that have modified entitlements in rather complex ways, differentiated across cohorts and skill levels.

Keywords: Accrued-to-date liabilities, microsimulation, pension reforms.

Estimations macro et microéconomiques combinées des droits acquis à retraite : une application aux réformes françaises

Résumé

L'indicateur des droits acquis à retraite (DAR) pourrait bientôt faire partie des indicateurs régulièrement disponibles pour le suivi des systèmes de retraite, en réponse aux nouvelles exigences du système de comptes nationaux. Ceci soulève deux questions : comment produire cet indicateur, et pour quoi faire ? Ce texte montre que la microsimulation est une réponse possible à la première question. Malgré son caractère stochastique, elle conduit à des résultats qui apparaissent suffisamment stables pour remplir des objectifs comptables. Concernant la question du « pour quoi faire», on sait déjà que cet indicateur n'est pas un indicateur de soutenabilité financière des retraites. Son message est plus intéressant du point de vue des ménages et plus particulièrement au niveau microéconomique. Ceci accroît l'intérêt de l'approche par microsimulation qui produit automatiquement des données cohérentes aux niveaux micro et macro. Ces propriétés micro et macro sont illustrées à partir du cas français, avec une application à l'évaluation des réformes de 1993, 2003 et 2010 qui ont modifié les droits à retraite de manière assez complexe, différenciée selon les générations et les niveaux de qualification.

Mots-clés : Indicateur des droits acquis à la retraite, microsimulation, réforme des retraites.

Classification JEL : C53, H55, J26.

Introduction

Implicit pension liabilities (IPL) are an indicator that can be computed in three main distinct ways. One first version takes into account all the future flows of benefits and contributions to be paid or to be received by the pension system, i.e. the "open system" (OS) approach. The two other ones focus on people already present in the system, with the two sub-cases of the "accrued-to-date liabilities" (ADL) approach, restricted to benefits to be paid on the basis of past contributions, and the "closed group" (CG) approach, that also incorporates contributions to be paid by current participants until the end of their working lives, compounded with the additional benefits that these future contributions will generate.

It is only the first of these three indicators that sends clear messages about what is needed to warrant the sustainability of a pay-as-you-go (PAYG) pension system: the indicator is positive or negative depending whether future expected paiements cover future expected expenditures or not. ADL and CG approaches do not send such a clear message concerning pension sustainability (Eurostat/ECB, 2008; Blanchet and Ouvrard, 2007). A given pension system can have very high IPLs according to the ADL and CG approaches while being perfectly sustainable: this will be the case for a large mature pension scheme which is in steady state equilibrium and for which IPLs in the OS sense of the term will be equal to zero. Conversely, a system that distributes low benefits but faces unfavorable demographic or economic prospects will generally require some reform to avoid prospective financial gaps, while being unduly considered in good standing by uninformed observers taking low levels of ADL or CG indicators as symptoms of financial health.

Despite this limit, ADLs could gain increased visibility in the future, if they become part of pension statistics regularly produced by national accountants, in compliance with the last update of the 1993 System of National Accounts (SNA). This new requirement has been introduced in order to harmonize the treatment of private pension funds and public pension systems. Computing ADLs for private schemes was already part of the core system of accounts, for the good reason that such private schemes require full funding: ADLs literaly measure the reserves required by such systems to face their commitments in the limit case of a sudden closing with a full interruption of the flow of contributions to the system. Such a scenario is in principle ruled out for public or government sponsored unfunded pension schemes, but the same kind of information is, in principle, now awaited from national accountants. New tables could be requested to provide both current estimates of these ADLs, and a decomposition of their changes over time, i.e. the increase in ADLs resulting from new contributions by active participants, and, on the negative side, the reduction of these ADLs corresponding to pensions paid the current year. Separate evaluations could also be requested concerning the impact of reforms on these ADLs, when such reforms take place.

This perspective raises two questions that are the topic of the current paper.

The first one is the question of the « how? ». Building ADL indicators is easier than computing full OS indicators, because it does not entail a full long run projection of all expenditures and receipts by the pension system: such undicators focus on elements of the pension contract that are predominantly rooted in the past, and here lies incidentally the basic reason why accountants favor this particular concept of IPLs. But this computation remains nevertheless difficult when pension rules are complex. One way to address this complexity of pension rules is microsimulation, because it allows a detailed account of all the legislation at the individual level. Microsimulation models are indeed a central instrument for pension projection exercises. Consequently, it is natural to wonder whether this same technique can also be one of the ways to fulfill new SNA requirements. Yet the answer to this question is not as self-evident at it may seem. The main reason is that microsimulation results are subject to stochastic variability, a characteristic that appears problematic for their introduction in NA statistics. This is all the more true here that, as mentioned, the new SNA requirements do not only ask for some snapshot figures of ADLs, but also for year to year changes in these ADLs and their components. The first contribution of this paper will be to show that this problem of stochastic variability is indeed present, but not at a point that precludes relying on this technique for routine production. We shall see that, even with a small scale microsimulation model running on a very limited sample, it looks possible to produce ADL indicators that look stable enough to be included in SNA tables. In other words, microsimulation is one possible answer to the question of the « how ».

The second question addressed by this paper is the question of the « what for? ». If it is acknowledged that ADLs cannot be used as sustainability indicators, what will be the most relevant way to use them once they will be regularly produced? For instance, how should we use the information they will deliver concerning pension reforms? Relying on our microsimulation results, we shall be able to examine this question taking recent French reforms as an illustration. Consistently with the view that ADLs are not a sustainability indicators, we will show that they are not very informative concerning the contribution of reforms to the restoring of pension sustainability. The information that they provide is clearly more relevant when looked at from the point of view of households, as indicators of prospective pension entitlements. Restoring sustainability generally entails cuts in these entitlements, either through reduced benefits at given retirement ages, or through a shortening of the retirement period at given replacement levels. The advantage of the ADL approach is to produce a synthetic view of how these two kinds of changes affect individuals or households.

Now, it immediately stands out that such an information is much more interesting at the micro-level than at the macro one. One additional limit of ADLs computed at the very global level is that they give a predominant weight to people who are close to retirement who, in general, are not the ones who are the most strongly affected by reforms. Hence the importance of looking *within* the indicator. This will give an additional argument in favor of the microsimulation approach to ADL evaluation since this approach will very easily permit the production of consistent results both at the macro and micro levels. Such a perspective is in line with the current attempts to develop household accounts disaggregated by socio-demographic categories (Fesseau *et al.* 2008).

The paper is organized as follows. The first section will come back on the features of the French pension system and of its reforms that need to be known in order to understand the rest of the paper. Section 2 will briefly present the main characteristics of the microsimulation model used in this paper, the Destinie 2 model (Blanchet *et al.*, 2010) and how it has been used for building ADL estimates. Sections 3 and 4 will discuss macro results. Section 5 will be devoted to some illustrative micro-results. A technical appendix is devoted to the demonstration of some analytical results concerning steady state values of ADLs that will be used in the paper for the validation of microsimulation estimates.

1 The French pension system and its reforms

Understanding the contents and consequences of French pensions reforms requires a minimal understanding of the organization of the system and of the rules governing eligibility and benefits. The French system is often considered as particularly complex and fragmented. We will not give a full overview of its organization in this paper, but will rather concentrate on the two major schemes that have been concerned by the three reforms that we shall analyze in greater details. These two schemes are the general regime that provides the basic first pillar pension for the vast majority of wage earners working in the private sector (between 60 and 70% of the employed labor force) and the regime that applies to public sector employees (about one fifth of the labor force).

Both regimes are characterized by a legal age at retirement that, since 1984 and until the last reform, was equal to 60. At this age, under normal conditions, a former private sector worker is, or rather used to be, entitled to a pension equal to 50% of a reference wage computed on the basis of his past wages, truncated to a "social security ceiling". At the same age (or sometimes at age 55 for some specific categories) a public sector employee is, or rather used to be, entitled to about 75% of his last treatment, excluding bonuses. The discrepancy between the two replacement ratios is compensated by the fact that the basic pension for the private sector is combined with one or two additional pensions served by two complementary schemes, ARRCO and AGIRC, the second one being specific to highly qualified white collar workers. In the public sector, there is no such second pillar.

Yet a good understanding of reforms requires some explanations of what was exactly meant by retirement at age 60 "under normal conditions". The lowering of the retirement age to 60 in 1984 did not establish a fully systematic access to a full rate pension at this age of 60, since a supplementary condition exists to get this full rate pension before the unconditional age that, until 2010, was 65 years. Until 1993, this condition was to have validated at least N*=37.5 years of contributions, either in the general regime or any other scheme. Not fulfilling this condition did not preclude the claiming of benefits, but imposed accepting a very strong reduction of the replacement rate, much stronger than the one implied by actuarial neutrality: this penalty consisted in a reduction of the benefit level by more than 10% for each year missing to reach 37.5 years or age 65. Getting a full pension at 60 in the public sector also required the same total number of years of contributions, although the penalty for a lower duration was, in this public sector, marginal, compared to the one applied in the private sector.

On this basis, the 1993, 2003 and 2010 reforms included the following elements synthesized in table 1.

The 1993 reform only concerned the private sector. Its most symbolic measure was a tightening of the 37.5 years condition: it scheduled a shift in this condition by one quarter each year until 2003, in order to reach the new value of 40 years. Although highly symbolical, this measure was not the one that was expected to have the largest effect in the short or medium run. Actually, cohorts that currently leave for retirement started working earlier than 20 on the average, and, thanks to the fact that periods of paid unemployment are validated as full years of contributions, a large majority of new retirees are still able to fulfill this duration condition at age 60, even after it has been raised to 40. More decisive reductions in expenditure levels were awaited from three more technical points:

- The first one was not a pure product of this 1993 reform but rather the confirmation of a policy that had started being applied in the late 80s, i.e. the indexation of current pensions on prices

Table 1: **Pre and post-reform major rules for the major basic French pension schemes**

	France, "régime general "				France, public sector employees		
	Before 1993	1993 reform	2003 reform	2010 reform	Before 1993	2003 reform	2010 reform
Minimum age	60	No change		Increased to 62 years in 2018	55 or 60, depending on categories	No change	Increased to 62 years in 2018
Condition for a full rate pension	A=A*=65 or N=N*=37.5 years of contribution	N* raised from 37.5 years to 40 years (in 2003)	N* raised to 41 in 2012, then indexed on life expectancy	A* raised to 67 in 2023	N* =37.5 years	N* raised to 41 in 2012, then indexed on life expectancy.	A* raised to 67 in 2023
Pension level	50%.(N/N**). average of the D* best wages, truncated to SS ceiling, with D*=10 and N**=37.5	D* increased from 10 to 25 years (between 1993 and 2008).	N** aligned on N*		75%.(N/N*) of the last wage	No change	
Additional penalty for retirement before reaching A* or N*	10% reduction for each missing year	No change	Abatement lowered to 5% per missing year	No change	None	Abatement increased from 0 to 5% per missing year	No change
Bonus for retirement after N* or A*	None	No change	3% for each additional year, later increased to 5%	No change	None	3% for each additional year, later increased to 5%	No change

rather than on wages.

- The second derives from the first. By law, it is the same yearly coefficients that apply to the revalorization of current pensions and to the reevaluation of past wages used for computing the "reference wage" that is part of the pension formula. Reevaluating past wages retrospectively according to past inflation rather than according to past nominal economic growth mechanically results in lower initial pension levels for new retirees.

- The impact of this change has been at last amplified by a shift in the number of years of one's past career used for computing the reference wage, from the 10 best years of one's career to the 25 best years, by one year every year from the 1933 to the 1948 cohort. A reference wage computed on a sequence of 25 "best" years less generously reevaluated necessarily leads to a lower pension level than under a 10 best years rule with more dynamic reevaluation coefficients.

The second reform that took place in 2003 had the following main features:

- The first measure has been to organize a convergence of conditions for accessing to full rate pensions between the public and the private sector. The duration condition has been raised to 40 years in the public sector by 2008.

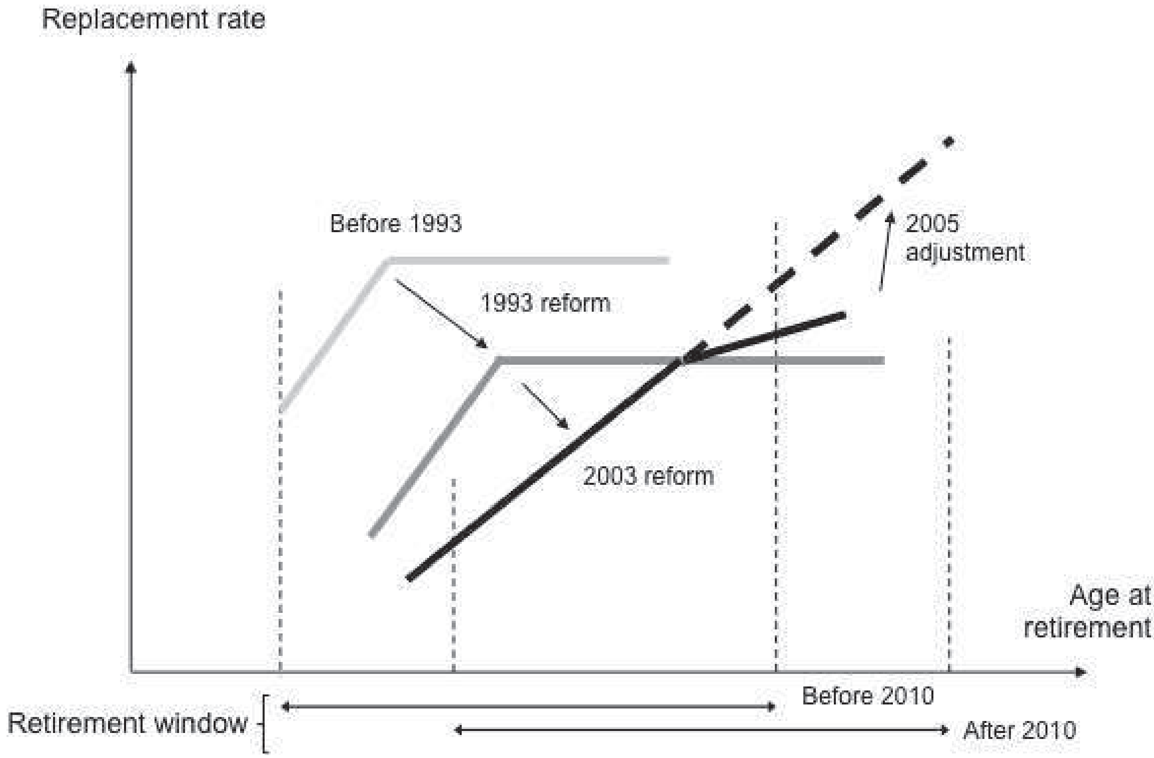
- After realization of this convergence, the duration condition common to the two sectors has been scheduled to be increased by one more year between 2008 and 2012. Thereafter, it follows a path indexed on future life expectancy gains, splitting these gains between 2/3 of additional length of working life and 1/3 of a remaining increase in the retirement length.

- In addition and partly in compensation for this strengthening of conditions for access to full retirement, more flexibility was introduced around this normal retirement age. We have previously mentioned the strength of the penalty that was applied by the French general regime in case of a departure before the full rate, and also the complete lack of financial incentive to postpone retirement beyond this age. The 2003 reform corrected this double anomaly by reducing the penalty for early retirement in the private sector (and conversely increasing it in the public sector where it was much weaker) and by introducing an incentive to postpone beyond that age, through a 3% pension bonus for each year of postponement. This bonus was later increased to 5%, to make it symmetrical to the penalty applied to retirement before the full rate.

These two reforms have therefore led to implicit changes of the "normal" retirement age, at least for the groups of people reaching 60 without the requested number of years of contribution. But they did not affect the symbolic minimum age of 60. This has been done by the last reform in 2010, enacted to cope with the financial consequences of the economic crisis: the main feature of this reform has been a global shift of the age bracket for retirement. From the initial bracket of [60, 65], we shall move within a relatively short period of time to the new [62, 67] bracket. Given that changes occur according to cohort rather than time, the change will be completed by 2018 for the lower end of the bracket, and by 2023 for its upper end. To put it another way, people from cohorts 1956 and later will have to wait until 62 to start claiming for their benefits, with only limited derogations for people having started working very early, and those not reaching the N* condition before 67 will have to wait until this age to get a full rate pension.

The incidence of these three successive reforms can be grasped more easily using the stylized representation of figure 1 that gives the replacement rate under the successive rules, as a function of retirement age, in the specific case of a private sector employee not reaching the N* condition before the initial minimum age. Prereform conditions are described by the first broken line starting from the left, which is in light grey. Under these initial rules, this individual was exposed to an important penalty if retiring at 60, but could retire with a full rate pension slightly above this age, and did not get any additional benefit from postponing further. The final effect of the 1993 reform has been to move this profile both rightwards and downwards, i.e. more years to wait until the full rate and a lower pension for this new retirement age, but without any other change in the shape of the profile (medium grey line). The 2003 reform did not reduce anymore the level of pension at the full rate, or only marginally, but went on moving rightwards the age for this full rate (dark line). On the positive side, it reduced the penalty for departures before this full rate, and introduced the new possibility of reincreasing one's pension level by postponing beyond the full rate, thanks to the new bonus of 3% per year of postponement, later raised to 5% (dashed line). Lastly the 2010 reform did not modify again the general shape of this age/replacement rate profile, but moved rightwards the age bracket over which this profile applies: this

Figure 1: *Stylized incidence of successive reforms, for an individual reaching the full rate after the minimum retirement age*



is described on the graph by the parallel moves of the two vertical lines describing the minimum age and maximum retirement ages. This graph illustrates in a simple way the fact that the 2010 reform and the previous ones have acted or will act quite differently on different categories of people: while the 1993 and 2003 reform mainly increased the normal or full rate retirement ages for people having started their careers later than the average, i.e. generally more highly skilled people, the 2010 reform will mechanically affect all the people who, even after these 1993 and 2003 reforms, could still retire at 60, i.e. people having started working and contributing before their 20s, generally less skilled workers. This is precisely the kind of message that we shall retrieve later when moving to the computation of ADLs by socio-demographic groups.

2 Simulating the impact of pension reforms and computing ADLs: the Destinie 2 model.

Before moving to these results, we must however discuss why and how microsimulation helps assessing the quantitative consequences of these reforms. The preceding section has emphasized the complexity of the French pension system. We have seen that this complexity is twofold. The first element is the coexistence of several different schemes: we have presented only the two most important of these, without developing the characteristics of schemes applying to self employed people, nor the rules of complementary schemes that complement pensions for private sector employees, both below and above the social security ceiling. The second dimension of this complexity is the complexity of rules within each of these schemes. Figure 1 was particularly illustrative of this, showing the strong non-linearities of the age/replacement rate relationship in the general regime and the way it has changed or will change over time. Precise simulations of the impact of parametric reforms with such complex rules is almost impossible to do with aggregate or semi-aggregate models. Such models can be used as long as the question is to look at the macro-incidence of very global variants such as demographic variants or variants affecting productivity growth or employment rates. But they are of no help anymore when we want to answer more precise questions.

For instance, even if we limit ourselves to the general regime, table 1 and figure 1 show that we both need to know the full distribution of the number of years of contribution by people reaching the age of 60, and the dispersion of career profiles, necessary for a correct evaluation of the replacement rate. The first element can eventually be made available in a cell-based model projecting the cross-classification of individuals by age and number of years of contributions (see e.g. Aubert *et al.*, 2011). But this would not provide any answer to the second problem. In such a context, there is a strong motivation to rely on microsimulation and this is the strategy that has been followed since the mid 1990s at INSEE with the building of the Destinie microsimulation model (Bardaji *et al.*, 2003; Blanchet and Le Minez, 2009) and used also by the "régime general" for its own projection exercises (Poubelle *et al.*, 2006).

We shall not review here the complete characteristics of this model, but only the ones that are relevant to the present exercise. The current version of the model that has been developed since 2005 (Blanchet *et al.*, 2011) works in two steps. The first step consists in a projection of demographic characteristics -including family ties- and of labour market trajectories of a sample representative of the French population. This is done starting in 2003, which is the current base year for the model. The choice of this base year is due to the fact that most of the initial information used by the model currently comes from a survey conducted in 2003, the *Enquête Patrimoine*. The main advantage of this survey is that it provides us with full retrospective information on past labour market trajectories of individuals.

Another major characteristic of this first component of the model is that it does not deal at all with pension issues. It even does more than that: it reconstructs or projects potential labour market trajectories beyond standard retirement ages, up to the conventional age of 70, based on year to year matrices of labour market transitions. The idea is to make available to the user a set of given potential labour market histories, whose interruptions through retirement will be only simulated during the second step. This second step of the simulation re-reads the full biographies generated by the first module, and uses them to simulate the consequences of pension scenarios.

Two important points are to be mentioned concerning this two-tier structure:

- First of all, the separation between the two steps means that it is possible to simulate the consequences of pension reforms on a population whose characteristics outside pensions are completely fixed. Such would not necessarily be the case in a model simulating demographics, labour market transitions and retirement in one single pass where interferences are difficult to avoid between stochastic drawings used to generate the different categories of events. This characteristic of the model allows *ceteris paribus* comparisons of reform/no reform scenarios that are not polluted by

Table 2: **Projection assumptions**

	2003 to 2010	2010 and after
Scope	Resident population, main regimes: "régime général" and complementary schemes ARRCO/AGIRC for private sector employees, one-pillar scheme for civil servants, basic first pillar schemes for self-employed workers. Only personal entitlements are taken into account. Household level benefits (old age minimum) and survivor's pensions are excluded from the analysis.	
Demographic assumptions	According to Insee's 2006 demographic projections	
Macroeconomic assumptions	Unemployment rates and growth rates for GDP and wages aligned on observed changes	Consistent with scenario "c" of projections by the Pensions Advisory Committee (*Conseil d'Orientation des retraites*, 2010), i.e. long run unemployment rate of 7%, productivity growth rate of 1.5% per year
Discount rate	3% (with 2% and 4% variants)	
Main pension rules	Without or with main changes introduced by the 1993, 2003 and 2010 reforms, depending upon no-reform/reform scenario	
Other pension rules (complementary schemes, indexation rules for basic schemes)	According to past evolutions until 2010.	After 2010, systematic indexations on prices.

uninformative noise: the only source of imprecision in the comparison is the fact that the basic sample may stochastically under or over represent people more or less affected by the reform, but we avoid the uncertainty that would result from stochastic variations between two distinct "reform" and "no reform" samples.

- Second, the second tier does not only project pension status and pension levels, but it also reconstructs them for all the initial stock of retirees. Initially, this choice has been made for a purely technical reason which was to avoid having results affected by stock/flow discrepancies that are inherent to most projections exercises of this kind. Whatever the qualities of both the initial survey and the projection model, we know that it is never possible for both of them to be fully consistent and this may lead to inadequate behavior of the model in the short and medium run, for instance pensions that decrease or increase in the short run because either the model neglects some secondary components of the pension formula that are present in the stock variables, or because these self-reported stock variables over- or underestimate the true level of pensions. Reimputing initial pensions and past ages at retirement of the initial stock of pensioners avoids such discontinuities. Now, for our present topic, it has one interesting by-product. This systematic imputation of pensions can be done under any form of retrospective pension rules so that the model can easily generate a counterfactual initial situation in 2003 that does not correspond to the consequences of the true legislation that has prevailed until 2003, but to any other legislation. In particular, it will be possible to produce an initial evaluation of pensions or ADLs in 2003 corresponding to the pre-1993 legislation, to see how this first reform had already impacted pension liabilities in 2003.

Moving to the way ADLs have been computed by the model for the present exercise, the organization is the following, for a given scenario.

a) The basic structure of the simulation program is the same as for any standard projection. We perform a standard simulation of projected retirement ages and pension entitlements using assumptions described in table 2. The structure of the simulation program is the typical structure of a dynamic microsimulation model working by period, with two nested loops: one primary loop on the time index, and one secondary loop covering all individuals in the population for each time period. Within this second loop, two operations take place for individuals who are present in the population and already retired or reaching retirement ages. For those not yet retired, the model simulates whether the individual chooses to retire. The model offers various options for simulating this retirement decision: here we simply assume that individuals retire when they reach the full rate. Then, when the individual retires, the model modifies his labour market status accordingly, and computes the different components of his pension (there can be up to 5 components given that the model simulates mixed careers) and their sum. For individuals already retired, what the model does is simply to update the pension level according to prevailing indexation. For the retrospective part of the simulation (until 2010), indexation takes place according to observed rules. For the prospective part of the simulation, indexation on prices is assumed.

b) The simulation of ADLs at the individual level then takes place every year within the individual loop. Here also two cases are to be considered.

b.1) If the individual is already retired, we just have to multiply his current pension by his remaining life expectancy, adjusted for discounting. One possibility in a microsimulation model would have been to use the number of remaining years of life as simulated individually by the model. This is all the more possible here that age at death is simulated *ex ante*, by the first module, and is therefore already known when simulating pensions. But this solution could not work for individuals dying after the horizon of the simulation, which is here 2050. Furthermore, even if this information on age at death had been available for all individuals, using this simulated information would have added unnecessary stochastic noise in the result. We therefore rather choose to use the standard actuarial formula based on the discounted sum of expected survival probabilities. These probabilities are those derived from current mortality, differentiated by gender, i.e., when we are e.g. in year 2015, the projected ADL of a person retired at this period is based on mortality tables of year 2015, not on cohort tables including later gains in life expectancy. But this restriction could be easily avoided if requested.

b.2) If the individual is not retired, the computation is more complex. The steps are the following. In order to avoid modifying the characteristics of this individual, we first create a clone of him/her, whose life path will be projected into the future. Two sub-possibilities have been considered:

- One consists in simulating what would be the future entitlements of this individual fully applying the conventional assumption of an immediate closing of the system. In that case, for most of the people, this will imply arriving at retirement ages with lengths of the contribution period much shorter than the one going to be required for the full rate. As a consequence, the retirement age simulated for the clone will generally be equal to 67. Then, the ADL can be computed by multiplying the pension reached at this age by the discounted life expectancy at this age of 67, with two additional corrections corresponding to discounting and to the incidence of mortality between the current age and 67. Consistently with the choice made for the mortality of people already retired, all the mortality parameters used for this part of the computation refer to period mortality, only differentiated by gender.

- The other is to take advantage from the fact that the model directly provides prospective careers, at least until 2050, that can be easily extended further. We therefore use these simulated prospective bibliographies to project full career pension entitlements, again under the assumption of retirement at the full rate, but at ages that are now going to be more frequently lower than 67, which sounds more realistic. We then correct these complete pensions to reflect accrued-to-date entitlements through a simple proratization formula. If we are at period t for an individual aged a expected to retire at age r, his projected pension is multiplied by the number of years of contribution reached at this age a, divided by the total number of years of contribution expected at age r. We then introduce pre- and post retirement mortality in the same way as with the previous option.

None of these two formulas is fully satisfactory, the first one because it refers to a highly counterfactual scenario for the pension system -the closing of the system, moreover immediately, is not realistic-, the second one because the simple proratization formula does not exactly reflects the way entitlements are progressively accumulated for the individual. In practice, they however give relatively similar results. Since the incidence of choosing between either of these two options or other possible variants of them is not decisive for the messages of the current paper, we shall restrict ourselves to presenting results from the second approach.

Once this is done for each reform scenario, we end up with a three dimensional table whose generic element $ADL(s, i, t)$ gives accrued-to-date liabilities for individual i at time t under scenario s. This allows producing many sets of statistics.

- Global ADLs at time t will be produced by simply summing up over i at given s and t.
- We can compute variations in ADLs over time or at given time period between two distinct scenarios.
- All these computations can be reproduced for specific subgroups, for instance the incidence of reforms on ADLs by age or other socio-demographic characteristics.

All this exercise being itself included in a standard projection exercise performed with the same model, messages from ADL indicators can be compared to the ones given by more standard pension indicators, such as the ratio of pensions to GDP.

We also underline the possibility offered by the model to *anticipate* future changes in ADLs: they are not computed only for the current period, but can be projected as far as desired, even if we stop here in 2020. Such a possibility is, for sure, quite uncommon among other SNA statistics. Under real conditions, we are not expected to use it for delivering corresponding tables of accounts years in advance: yearly deliveries will always require some adjustments incorporating new unanticipated changes in macroeconomic conditions and pension parameters. They will have to be introduced into the model year after year, as parts of its systematic updates, and such has been already the case for the 2003-2010 segment of results that will be provided in this paper. This segment of the projection

Table 3: **Total ADLs in 2011, for three values of the discount ratio**

	Discount ratio		
	2%	3%	4%
Total (billion Euros of 2006)	7141.8	5919.2	4999.8
% of GDP	377	312	264

Source: Destinie 2 model, authors' calculations.

includes some alignment of simulated employment and wage trajectories on the new macroeconomic conditions induced by the economic crisis, as well as the incidence of the 2010 reform that was not anticipated at the time the model started being built. However, being able to build *ex ante* baseline scenarios for these ADL statistics should offer some security for their yearly production: we shall be always certain to have at hand one first round estimate of this indicator that, normally, will only require marginal adjustment.

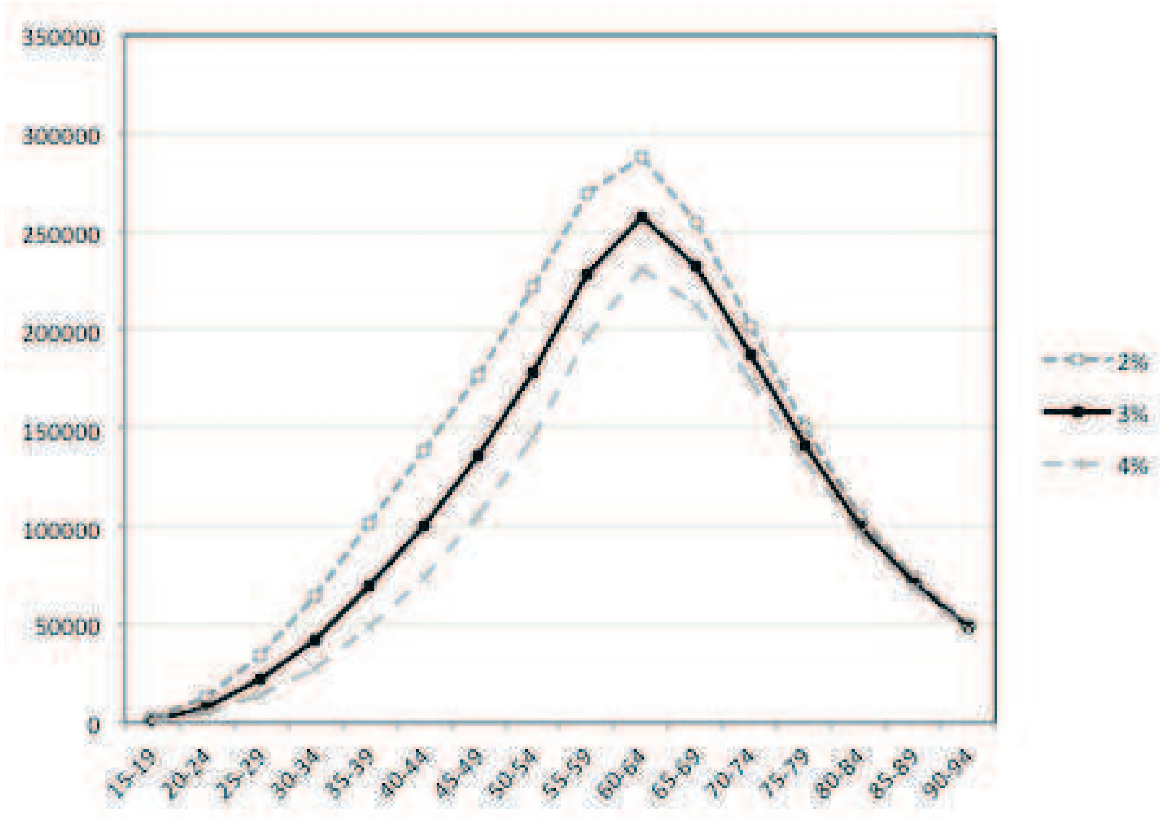
3 First results: point estimates of age specific profiles and global implicit liabilities

Let's turn to results. Figure 2 starts by showing the age-profile of individual ADLs, in 2011, i.e. after the 2010 reform, simulated over a sample of about 6 000 individuals.[1] The profile has the typical bell-shape that was expected. ADLs are close to zero for young contributors because they only have a few years of contributions behind them, and because the limited flow of benefits stemming from these few years of contributions is discounted to a very distant future. Liabilities then increase with age and peak around 60, i.e. at an age where people have had the time to accumulate full entitlements, whose actuarial value will be discounted over their entire retirement period. Liabilities decline after that peak because we consider pensions that remain to be paid on a number of years that itself declines with age. When aggregating, the liabilities of older retirees will be further dampened by the fact that the number of surviving retirees is itself decreasing rapidly at older ages. After this aggregation, we get results provided on table 3, which shows both the high magnitude of the ADL/GDP ratio, around 3 years of GDP, and its strong dependency upon the chosen discount rate.

Results can be compared with some other estimates. Some evaluation provided during the 90s already pointed at values comprised between 2.1 and 2.8 years of GDP (Vernière, 1992, Van der Noord and Herd, 1993 and Chand and Jaeger, 1996). Closer from our estimates, Blanchet and Ouvrard (2007), using the earlier and completely independent "Destinie 1" model, found an amount of between 3.2 and 4.7 years of GDP, using the same values of the discount factor, but with a larger perimeter, since their evaluation also included survivors' pensions. Last, Durant and Frey (2010) using the cohort based PROST model built by the World Bank (Holzmann et al., 2001) reckon a total amount in 2008 of 7 976 current billion euros, with a discount rate of 2%. All these estimations are not directly comparable,

[1] In its current version, the Destinie 2 model can run on two samples: a small sample of about 6 000 individuals and a larger one of 60 000 individuals, corresponding to respectively 1/10 000th and 1/1 000th of the French population. All results presented here are based on the small sample.

Figure 2: *Age profiles of liabilities according to the ADL methodology, in 2011, for three values of the discount rate (average individual values within 5 year age groups, in 2006 euros)*



Source: Destinie 2 model, authors' computation

due to differences in methods and in scope, especially for the oldest ones. But all point at a very large value of these commitments.

To validate such evaluations and their sensitivity to the discount factor, it is useful to refer to some steady state analytical properties of this ADL indicator whose derivation is provided in the technical appendix.

First, in steady state, i.e. with a stable age structure of the population, with wages increasing at a constant rate, with pension rules fully stabilized, and a discount rate equal to the growth rate of the economy, one first formula tells us that the ADL/GDP ratio is equal to the pensions/GDP ratio, multiplied by the difference between the averages ages of the pensioner and the average age of the worker/contributor, that is:

$$\frac{ADL}{GDP} = \frac{Pensions}{GDP}.(A_p - A_w)$$

This formula is relatively well-known and has been applied in other contexts (e.g. Settergren and Mikula, 2005).[2] It can be easily understood if we consider ADLs as the amount of reserves that should

[2]For a much earlier derivation of a similar formula, see for instance Bourgeois-Pichat (1978) and the related paper

be held at each period by an equivalent funded system. In such a system, the total amount of these reserves would correspond to amounts collected each year, multiplied by their average period of presence into the fund, i.e. the difference between the average age at which the worker pays contributions to the fund, and the average age at which he is paid back by the fund under the form of annuities.

This comforts the evaluation provided by Destinie. Excluding survivors' pensions and means tested benefits, the current size of the French system is about 10% of GDP, expected to increase to about 12% in the long run after inclusion of the impact of the last reform. Assume that the gap A_p-A_w is approximately equal to 30 years (i.e. 70 years - 40 years). For a discount rate equal to the expected growth rate -i.e. about 2%-, this means an ADL indicator representing between 300% and 360% of GDP, given that the current value of ADLs mixes information on both the current and the future size of the system. The value given on table 3 for this discount rate of 2% is broadly consistent with this computation, the fact of being slightly above being attributable to the fact that we are not under demographic steady state. More precisely, the bulk of baby-boom cohorts are currently in ages with higher than average ADLs, pushing up their global amount above this long run steady state value. Now, these high values are not, in themselves, sufficient to characterize a situation of disequilibrium for this PAYG scheme. Such high orders of magnitude are in no way specific of a situation of unsustainabilty: they also show up in situations of perfect sustainability where inflows of contributions permanently match outflows of benefits.

Analytical computations provided in the appendix also give a theoretical order of magnitude of the impact of the discount rate on the indicator. The formula now involves both the averages and the variances of ages at paying contributions and receiving benefits. It writes down:

$$\frac{\partial \ln(ADL)}{\partial r} = -\frac{1}{2}\left(\frac{V_p + V_w}{A_p - A_w} + (A_p - A_w)\right)$$

This formula leads to a semi-elasticity of liabilities with respect to r of about -18, i.e. a one percentage point increase of r leads to a 18% decline of ADLs. This is roughly equivalent to the differences observed between the successive columns of table 2.

4 Global effects of the 1993 to 2010 reforms

Once the results of our baseline simulation have been comforted by the comparison with analytical results, let us turn to the analysis of messages of this ADL indicator concerning the financial impact of pension reforms. Figure 3 shows evolutions over time of ADLs both in absolute terms and in multiples of GDP under 4 retrospective and prospective scenarios: a first, "pre-1993", scenario where the pre-1993 legislation is assumed to be maintained indefinitely, a second scenario and a third scenario entitled "with 1993 reform" and "with 2003 reform" where the reform process is supposed each to have stopped just after the corresponding reform, and at last the "with 2010 reform" scenario corresponding to the full incorporation of all reforms, including the last one in 2010. Figure 2 and table 3 were taken from this last scenario, just picking up its results for year 2011. ADLs are given on these graphs from

by Bourgeois-Pichat and Chapron (1979).

the initial simulation year to 2020. Figure 4 complements figure 3 by giving, for the same scenarios, projections of the pensions/GDP ratio, now pushed until the standard Destinie 2 horizon, i.e. 2050[3]. From now on, all results are using the assumption of a 3% discount rate.

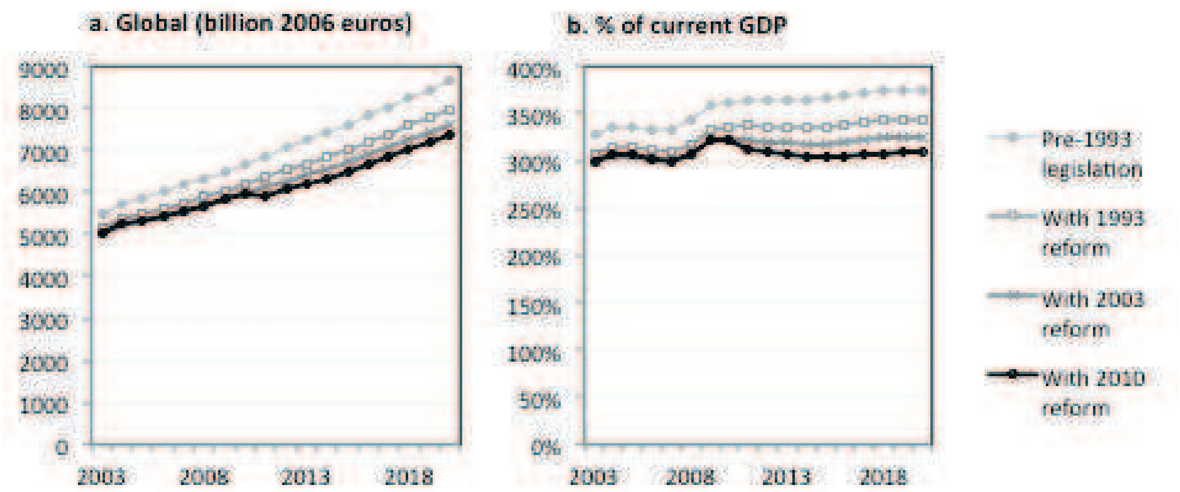
What are the main messages from these different graphs? The first point concerning figures 3a and b is the very smooth evolution of the indicator. This can be explained by the fact that it is a very broad aggregate, but also by the way it is simulated. If ADLs had been computed at successive periods based on independent samples, year-to-year fluctuations would have been probably much larger. But the principle of dynamic microsimulation is to follow the same individuals from their birth to their death. Sources of variations between two successive periods will therefore result only from entries and exits from this panel of participants to the pension system, and from changes of individual entitlements for people present in the panel at the two successive periods. Entries and exits are unlikely to generate strong stochastic fluctuations of global ADLs, because they concern age groups whose contributions to the global ADL are small: exits only occur in case of death, and predominantly affect people whose individual ADLs have already declined significantly since the time they got retired. Entries of new contributors, by construction, concern people whose immediate contribution to the global stock of ADLs is marginal. The main source of variation for global ADLs will be therefore year to year changes in entitlements of people present at both periods. For people in the accumulation phase, it will be more or less proportional to the global wage bill over the current period, which is itself a relatively stable output of the microsimulation program, especially when wages and global employment are aligned every year on macro-targets, as it is the case here. For people in the decumulation phase, it will correspond to global payments of pensions, which, despite being a bit less stable than the simulated wage bill, still have relatively smooth profiles, even on the sample of very limited size that is used throughout this paper.

This regularity of evolutions for "normal" periods allows observing very neatly the impact of both the economic crisis and the 2010 reform. Indicators expressed in % of GDP increase at the onset of this economic crisis due to a pure denominator effect. In such a context, the growth of global ADLs is not or only marginally affected, but changes in the rate of growth of GDP are reflected one-for-one in the relative indicator. We have the same phenomenon on figure 4 since this property of inertia applies as well to the current flow of pensions paid to retirees. It is precisely this divergence between the trend of pensions and changes in resources indexed on GDP that has been at the origin of this 2010 reform.

Then, the impact of this reform can be very neatly observed on figure 3a. It takes place in one single year: it is one of the virtues of the indicator to immediately incorporate all the information on the prospective impact of the reform. Evolutions are more progressive for the ADL/GDP and the pensions/GDP indicators, but these indicators combine the pure impact of the reform and, once again, a denominator effect now resulting from the reacceleration of economic growth that has been assumed in projection. Concerning the ADL/GDP ratio, the evolution is the result of the immediate drop in ADLs and of this progressive denominator effect. In the case of the pensions/GDP indicator, both the denominator and the reform effect are progressive. The latter one extends until the reform has produced its largest effects on ages at retirement, i.e. 2018.

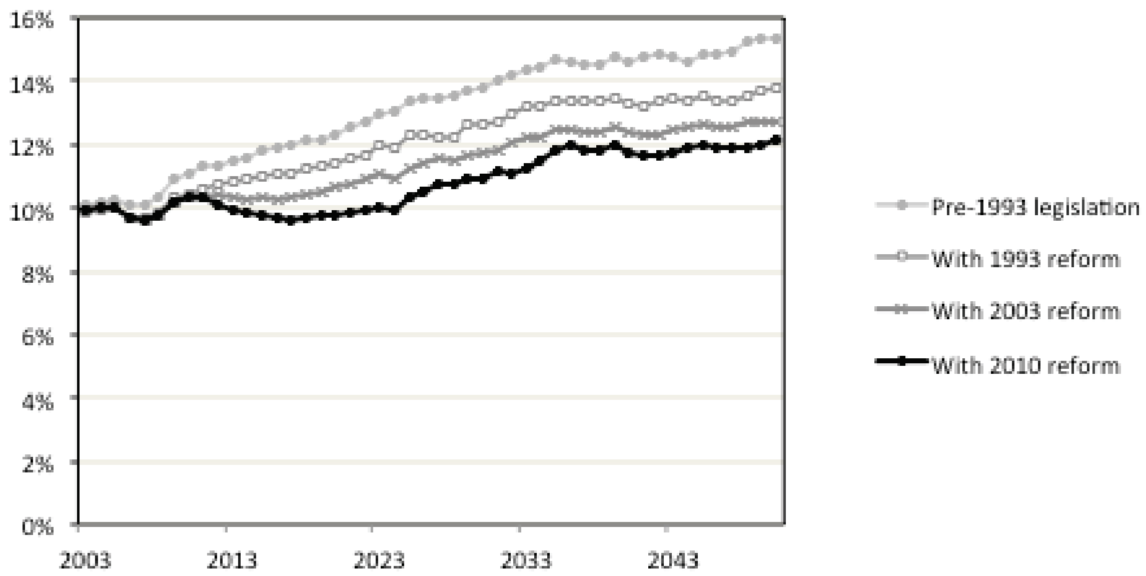
[3]These projected pensions/GDP ratios do not fully correspond to those more recently provided by the French pension advisory committee (COR, 2012). Discrepancies result from different assumptions concerning retirement behavior as well as demographic and economic trends (new projections by the COR use updated demographic projections issued by Insee in 2011 and revised assumptions concerning the time profile for economic recovery). Part of the difference may also be due to differences in scope, in particular our exclusion of survivor's benefits.

Figure 3: *Global ADLs according to reform scenario: past and projected evolutions*



Source: Destinie 2 model, authors' computation

Figure 4: *Projected pensions/GDP ratio*



Source: Destinie 2 model, authors' computations

Now, if we turn to the contributions of all successive reforms to long run sustainability, messages sent by the various indicators are clearly differentiated. The most adequate message is undoubtedly the one provided by the pensions/GDP ratio. Figure 4 shows that, without any reform, the pension system would have required increases in contribution going as high as 5 points of GDP in 2050 -after incorporation of the crisis effect. Successive reforms have quite substantially reduced this, with a cumulated effect of 3 points of GDP in 2050, but this is not completely sufficient for restoring financial equilibrium, since 2 more points of GDP remain to be found in the long run. Incidentally, this graph shows the relative impact of the three successive reforms, with an impact of the last 2010 reform that is relatively strong in the short run, but becomes less important in the long run (see Lellouch et al., 2011, for comparable results). The result is due to the sole use of the minimum retirement age as an instrument. In the short run, this instrument strongly reduces inflows of new retirees. But, in the long run, its financial efficiency is reduced due to two elements. First, even without this new reform, the impact of the two earlier ones would have been to significantly increase the age for getting the full rate pension. As a consequence, increasing the minimum retirement age affects a proportion of retiring cohorts that is increasingly small. Second, by constraining some people to postpone retirement, the reform also affects positively their pension level, an evolution that partly compensates the fact of having less retired people.

What would be now, on the same question, the conclusions of an observer only equipped with the information delivered by figures 3a and 3b? If this observer believes that it is *trends* in ADLs that matter, he could eventually conclude from figure 3b that the 2010 reform has fully restored long run financial equilibrium, since is has brought back the ADL/GDP ratio to its pre-crisis level. Such a conclusion would be over optimistic: even if the simulations suggest that the 2010 reform has solved short run diffficulties, it remains that some adjustments still have to take place in the longer run. If, on the other hand, this observer believes that it is the *level* of the ADL/GDP ratio that matters, he would unduly conclude to a relatively marginal impact of reforms, which, globally, have done no more than reducing the ADL/GDP ratio from 350% to 300%, i.e. a reduction of only 17,5% of the implicit pension debt. This would be conversely far too pessimistic, at odds with the message of figure 4 which is that, all included, reforms have solved a fraction of the financing problem that is closer to three fifths.

Such a low sensitivity of ADLs to reforms has been pointed at by other authors, see in particular Werding (2006) for Germany. This apparent paradox can be easily clarified if we go back to the long run interpretation of the ADL as the product between the annual flow of pensions and the difference $A_p - A_w$. This difference being relatively stable, this means that the ADL concept must basically be interpreted as an indicator of the *size* of the system, the only transitory difference with the pensions/GDP ratio being that the ADL gives some more weight to future pensions. In other words, for a given value of the $A_p - A_w$ difference, the ADL gives an information that is an average between the current and the future size of the system. Now, reforms aiming at restoring sustainability do not aim at all at massive reductions of the future size of the system. For a PAYG system trying to stabilize its contribution rate, the issue is only to limit the growth of the system, not to reduce its size below its current value. Hence, if the no-reform scenario points at a 50% increase of this size in the long run, as suggested by figure 1, what we need is a reduction of 50/150=1/3 of this future size. Reforms that reach 60% of this objective reduce this size by only 20%. We come close to the impact of reforms of -17.5% found with the ADL indicator, whose variation is further dampened by the relative weight it gives to people currently retired or close to retirement, who are generally less affected by reforms than younger age groups.

The only reforms that would very significantly reduce this size of the system and the ADLs would be reforms that would *substitute* funding to existing PAYG transfers. ADLs are indeed a useful indicator for countries that consider that PAYG financing is by nature unsustainable and aim at replacing it by fully funded systems, but this is not the kind of reform we generally have to evaluate.

This conclusion directs toward a different use of ADLs. This indicator is not that informative about the degree to which pension reforms improve the sustainability of the pension system, because ADLs remain high by nature even in a system that is perfectly sustainable. But its micro components consisting in ADLs for various categories of individuals provide a simple way to evaluate how the reform affects these various categories of individuals. This is what the next section intends to illustrate.

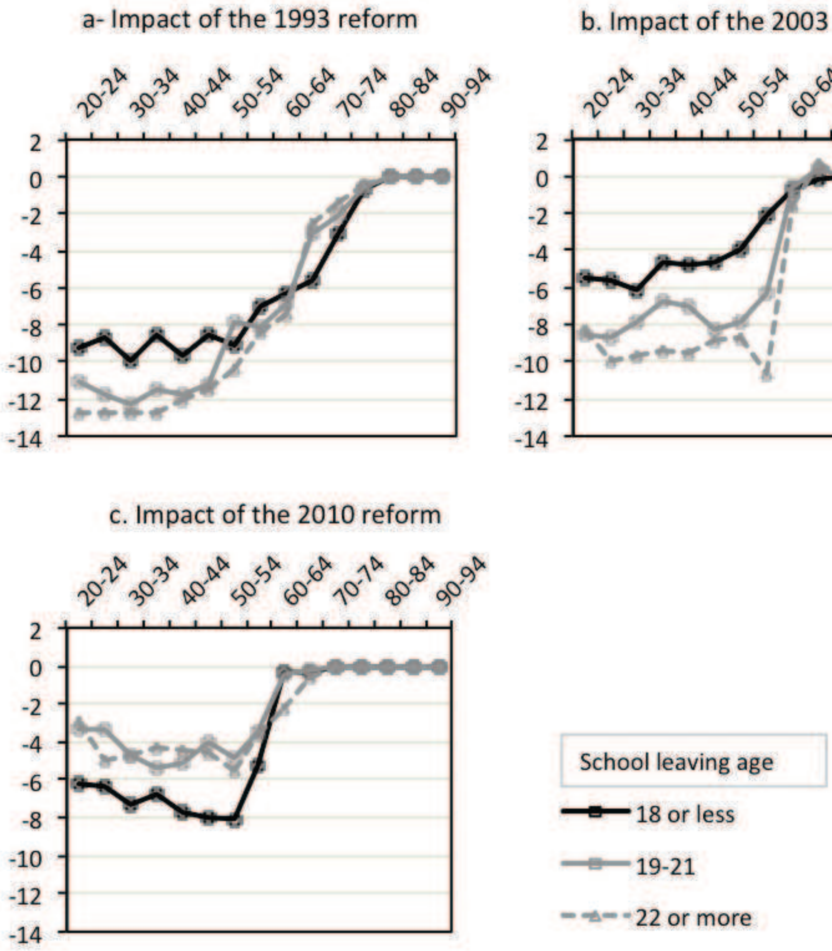
5 How do reforms affect ADLs across socio-demographic groups?

The -17.5% change in 2011 global ADLs resulting from the three successive reforms is a weighted average of the incidence of these reforms for various socio-demographic groups. How has this global change been shared among those groups? The calculation is straightforward given that ADLs have been computed, under the different scenarios, at the individual level. It would even be possible to compute fully individualized changes in entitlements since, as explained above, the conception of the model implies that the various reform scenarios are applied in all four cases to exactly the same individuals, with exactly the same characteristics from one scenario to the next, except for changes imputable to the reforms themselves. Here, we will not go down to this microeconomic level, but consider average changes for groups of individuals, classified by age/cohort and level of education. The choice of a breaking down by age is self-evident: reforms generally come into force progressively, and are expected to have a stronger relative impact on younger cohorts. Education level or more precisely the age at exit from the schooling system has been chosen as the secondary variable because it is the main variable available in Destinie for describing social stratification. Three groups will be considered: people leaving school at 18 or before, people leaving between 19 and 21 included, and people leaving after 21.

Results are reported on figures 5a to c that give successive relative changes brought by each reform compared to ADLs resulting from the previous reform, or from the no reform scenario in the case of the 1993 reform. Using relative rather that absolute variations neutralizes the impact of discounting or of the correction factor that is applied to young workers to account for their limited past record of contributions. These variations give us quasi-pure measures of entitlements as they will stand at the moment each age group will actually retire, depending on what will be its pension level and the expected length of its retirement period.

These graphs show interesting contrasts between the impacts of the various reforms. If we look at them along the age dimension, none of the reforms have impacted people currently retired at the time each reform was implemented. A small decline in ADLs is admittedly observed for people between 60 and 70 following the 1993 reform, but this is only because what we compare are ADLs as evaluated in 2011, i.e. 18 years after the reform took place. People belonging to the youngest age groups of retirees in 2011 have indeed been affected by the reform, but were not retired when this reform occurred. This

Figure 5: *Impact of the three successive reforms on individual ADLS by age and school leaving age*



Source: Destinie 2 model, authors' computations

absence of apparent impact of reforms on people retired at the time they took place should not be interpreted as meaning that retirees have not been put to contribution since the end of the 1980s, but this has been done through other routes, first the shift to indexation of current pensions on prices that had already been put into practice at the end of the 1980, followed by a reform of health care financing in the mid-1990s that increased the contribution of retirees compared to the contribution of working age groups.

Then, figures 5a and b show relatively progressive profiles in efforts demanded to successive cohorts, with an intensity roughly stabilizing for people younger that 40 in 2011. It is for the 1993 reform that the progressivity accross cohorts has been the most pronounced. One of its major aspects has been the increase in the number of years over which the reference wage is computed, from the 10 best years to the 25 best years, by one year every year, meaning that the process only came to its end for cohorts retiring 15 years after the reform, that is born in 1948. The length of the process is still increased by the fact that is has been combined with a less generous rule for actualizing past wage records when the pension is computed, whose impact will be fully complete when people reaching retirement will have had all their wage records reevaluated according to this rule. The other change has been a little more rapid, i.e. the increase from 37.5 to 40 years of the condition required to get the full rate at age 60, but this change also took place very gradually, from cohort 1933 to 1943 and its effectiveness is also made still more progressive due to the fact that the new condition only affects progressively cohorts that, until those born in 1960, had predominantly left school earlier than 20. This explains also why, even in the long run, the category with the lowest education level remains less affected than the two other ones.

The 2003 reform also has an effect that is progressive accross skill groups, more progressive than with the 1993 reform. Less skilled workers remain protected by the fact that many of them still reach the age of 60 with the requested years of contributions, even after its new increase from 40 to 41 and its subsequent indexation on life expectancy. The larger and more rapid impact on people with higher educational achievements also comes from the fact that this reform enacted a relatively rapid alignment on private sectors rules for public sector employees, that had been spared by the 1993 reform, and more educated categories are overrepresented in this public sector.

Last, the 2010 reform shows a rather different image, both by age groups and education groups. Categories the most affected are people of lower education groups and who are close to retirement: these people having started working early had been little affected by policies based on the criterion of career length. This is no more the case when it is the minimum age that is impacted, and the impact is rapid because the increase of this threshold is itself rapid, supposed to take place in only six years. This policy makes less difference for more educated groups who, even without this reform would have been already pushed to leave later than the age of 62.

These graphs are only illustrative. Going further would have required working on a sample of higher size, but they are enough to illustrate the possibilities of an indicator that combines the two dimensions of the pension level and the length of the retirement period. Many analyses of pension reforms look at both dimensions separately, and this is of course necessary, but the combined view is also informative.

6 Conclusions

This paper presented a tentative application of the Destinie 2 microsimulation model to the evaluation of pension liabilities in France. This model is still in its validation phase and the detailed values of results that have been presented must be interpreted with caution. They are preliminary and likely to be revised and refined in the near future. But some lessons can nevertheless be drawned.

First, from a technical point of view, it appears that deriving ADLs from a microsimulation model is technically easy once such a model is already available for other purposes. It allows the computation of these liabilities under a variety of scenarios. It also allows a consistent estimation of these liabilities at the macro and micro level. And the problem of stochastic variability that very often complicates the reading of microsimulation results appears, in this specific case, as relatively limited. This does not mean that some additional alignment on other NA aggregates will not be necessary in practice, but our results suggest that it may remain marginal.

As regards the interpretation of outputs, the conclusion concerning ADL indicators at the macro level is mixed, at least from the point of view of the follow-up of reforms aiming a restoring sustainability of PAYG pension schemes. These indicators react very little to such reforms, even when these reforms are of a significant importance. The reason for this low relevance of ADLs as indicators of reforms' financial impact is double. The first one is that they are above all indicators of the *size* of pension systems, whereas reforms generally only intend to limit the future growth of these systems, not to shrink their current sizes. Second, reforms generally limits the future growth of pension expenditures by reducing entitlements of younger cohorts, which are strongly underweighted in these ADL indicators.

It looks therefore more interesting to look at these indicators from the micro point of view, and section 5 provided some illustrations of such an application of the ADL methodology. Such an approach is in line with current efforts aiming at building more disaggregated household accounts, by socio-demographic groups. However, here also, ADLs are only one part of the story. For instance, reductions in entitlements are generally made with the purpose of avoiding increases in contribution efforts. Balancing the two effects imply looking either at life-cycle contributions/benefit balances or to rates of return on contributions. And a full picture of social consequences of reforms also involves looking at more standard indicators such as replacement rates, retirees' relative incomes or exposures to poverty risks.

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Appendix: Analytical derivation of ADL indicators under steady-state conditions

A.1. Notations

For simplicity, we assume all individuals enter into the labour force at the same age and our age counter a will take this point as origin. With this convention, retirement age R will also measure the length of working life. Other demographic parameters will be $N(0)$ the inflow of new entrants in the labour force for the current period, ω the maximum length of life, $s(a)$ the survival function between 0 and ω, and n the population growth rate. With these notations, if we assume steady state demographic growth, the number of people aged a is given by:

$$N(a) = N(0)e^{-na}s(a)$$

We then consider a period-specific profile $p(a)$ for pensions by age. Economic growth occurs at rate g in real terms and we assume that pension entitlements accumulate linearly over the active life span. This means that a worker aged $a < R$ at the current period can expect, at age u, a pension $(a/R)p(u)e^{g(u-a)}$ on the basis of his past participation to the system. If he is already retired, his expected pension at age u is just $p(u)e^{g(u-a)}$. It must be noted that this formulation is compatible with any assumption concerning the indexation rule for pensions after age R. For instance, if pensions are just indexed on prices, then we shall have $p(a)$ of the form $p(R)e^{-g(a-R)}$ and this will indeed imply pension prospects completely flat in real terms for a retiree all over his retirement period.

A.2. Steady state levels

To evaluate global ADLs, we distinguish two terms L_1 and L_2 corresponding to entitlements of people currently working and people currently retired. Let's start with the first group. If we discount at rate r, we get:

$$\begin{aligned} L_1 &= N(0)\int_{a=0}^{R} e^{-na}s(a)\frac{a}{R}\left[\int_{u=R}^{\omega} e^{(g-r)(u-a)}p(u)\frac{s(u)}{s(a)}du\right]da \\ &= N(0)\int_{a=0}^{R} e^{-(n+g-r)a}\frac{a}{R}da\int_{u=R}^{\omega} e^{(g-r)u}p(u)s(u)du \qquad (1) \end{aligned}$$

In the particular case $r = n + g$ that will be taken as a reference, this boils down to:

$$
\begin{aligned}
L_1 &= N(0)\int_{a=0}^{R}\frac{a}{R}da\int_{u=R}^{\omega}e^{-nu}p(u)s(u)du \\
&= N(0)\frac{R}{2}\int_{u=R}^{\omega}e^{-nu}p(u)s(u)du \qquad (2)
\end{aligned}
$$

For retirees, we get:

$$
\begin{aligned}
L_2 &= N(0)\int_{a=R}^{\omega}e^{-na}s(a)\left[\int_{u=a}^{\omega}e^{(g-r)(u-a)}p(u)\frac{s(u)}{s(a)}du\right]da \\
&= N(0)\int_{a=R}^{\omega}e^{-(n+g-r)a}\left[\int_{u=a}^{\omega}e^{(g-r)u}p(u)s(u)du\right]da \qquad (3)
\end{aligned}
$$

Assuming here again $r = n + g$ this expression becomes:

$$
L_2 = N(0)\int_{a=R}^{\omega}\left[\int_{u=a}^{\omega}e^{-nu}p(u)s(u)du\right]da
$$

Integrating by parts we get:

$$
\begin{aligned}
L_2 &= N(0)\left[a\int_{u=a}^{\omega}e^{-nu}p(u)s(u)du\right]_{a=R}^{a=\omega}+N(0)\int_{a=R}^{\omega}ae^{-na}p(a)s(a)da \\
&= -N(0)R\int_{u=R}^{\omega}e^{-nu}p(u)s(u)du+N(0)A_p\int_{a=R}^{\omega}e^{-na}p(a)s(a)da \\
&= N(0)(A_p-R)\int_{a=R}^{\omega}e^{-na}p(a)s(a)da \qquad (4)
\end{aligned}
$$

where:

$$
A_p = \left(\int_{a=R}^{\omega}ae^{-na}p(a)s(a)da\right)\bigg/\left(\int_{a=R}^{\omega}e^{-na}p(a)s(a)da\right)
$$

is the mean age at the perception of pensions. Reinterpreting accordingly $R/2$ in equation (2) as roughly corresponding to the mean age A_w at payment of contributions, and combining (2) and (4) we finally get:

$$L = L_1 + L_2 = P.(A_p - A_w) = \tau.GDP.(A_p - A_w) \tag{5}$$

with :

$$P = N(0) \int_{a=R}^{\omega} e^{-na} p(a)s(a)da \tag{6}$$

the global amount of pensions paid to retirees at the current period and using notation τ for the ratio of these global pensions to GDP.

A.3. Reactions to changes in the discount factor

We can then move on to derive how both L_1 and L_2 react to changes in r around the reference value $r = n + g$. Concerning L_1 we get from (1):

$$\begin{aligned}
\frac{1}{N(0)}\frac{\partial L_1}{\partial r} &= \int_{a=0}^{R} e^{-(n+g-r)a}\frac{a^2}{R}da \int_{u=R}^{\omega} e^{(g-r)u}p(u)s(u)du \\
&- \int_{a=0}^{R} e^{-(n+g-r)a}\frac{a}{R}da \int_{u=R}^{\omega} ue^{(g-r)u}p(u)s(u)du
\end{aligned}$$

which, around $r = n + g$ boils down to:

$$\begin{aligned}
\frac{1}{N(0)}\frac{\partial L_1}{\partial r} &= \int_{a=0}^{R} \frac{a^2}{R}da \int_{u=R}^{\omega} e^{-nu}p(u)s(u)du - \int_{a=0}^{R} \frac{a}{R}da \int_{u=R}^{\omega} ue^{-nu}p(u)s(u)du \\
&= \left(\frac{R^2}{3} - \frac{RA_p}{2}\right) \int_{u=R}^{\omega} e^{-nu}p(u)s(u)du
\end{aligned} \tag{7}$$

Concerning L_2 we get from (3):

$$
\begin{aligned}
\frac{1}{N(0)}\frac{\partial L_2}{\partial r} &= \int_{a=R}^{\omega} a e^{-(n+g-r)a}\left[\int_{u=a}^{\omega} e^{(g-r)u} p(u)s(u)du\right] da \\
&- \int_{a=R}^{\omega} e^{-(n+g-r)a}\left[\int_{u=a}^{\omega} u e^{(g-r)u} p(u)s(u)du\right] da \\
&= \int_{a=R}^{\omega} a \left[\int_{u=a}^{\omega} e^{-nu} p(u)s(u)du\right] da \\
&- \int_{a=R}^{\omega} \left[\int_{u=a}^{\omega} u e^{-nu} p(u)s(u)du\right] da
\end{aligned}
$$

which, integrating by parts, becomes:

$$
\begin{aligned}
\frac{1}{N(0)}\frac{\partial L_2}{\partial r} &= \left[\frac{a^2}{2}\int_{u=a}^{\omega} e^{-nu} p(u)s(u)du\right]_{a=R}^{\omega} + \int_{a=R}^{\omega} \frac{a^2}{2} e^{-na} p(a)s(a)da \\
&- \left[a\int_{u=a}^{\omega} u e^{-nu} p(u)s(u)du\right]_{a=R}^{\omega} - \int_{a=R}^{\omega} a^2 e^{-na} p(a)s(a)da \\
&= -\frac{R^2}{2}\int_{u=R}^{\omega} e^{-nu} p(u)s(u)du + \int_{a=R}^{\omega} \frac{a^2}{2} e^{-na} p(a)s(a)da \\
&+ R\int_{u=R}^{\omega} u e^{-nu} p(u)s(u)du - \int_{a=R}^{\omega} a^2 e^{-na} p(a)s(a)da
\end{aligned} \tag{8}
$$

Using the variance of the age at receiving pensions V_p, this formula can be rewritten:

$$
\frac{1}{N(0)}\frac{\partial L_2}{\partial r} = \left(-\frac{R^2}{2} + RA_p - \frac{V_p + A_p^2}{2}\right)\int_{u=R}^{\omega} e^{-nu} p(u)s(u)du
$$

Combining (7) and (8), we finally get:

$$
\frac{1}{N(0)}\frac{\partial (L_1 + L_2)}{\partial r} = \left(-\frac{R^2}{6} + \frac{RA_p}{2} - \frac{V_p + A_p^2}{2}\right)\int_{u=R}^{\omega} e^{-nu} p(u)s(u)du
$$

A more convenient version of this equation can be obtained if we observe that $V_w = R^2/12$, $A_w = R/2$ so that $V_w + A_w^2 \approx R^2/3$. Replacing, and introducting again P, the total pension bill, we get :

$$\frac{\partial(L_1+L_2)}{\partial r} = -P.\left(-\frac{V_w+A_w^2}{2}-\frac{V_p+A_p^2}{2}+A_wA_p\right) = -\frac{P}{2}\left(V_p+V_w+(A_p-A_w)^2\right)$$

that can be converted in a semi-elasticity of $L_1 + L_2$ with respect to r after dividing by (5). We ultimately get:

$$\frac{\partial ln(L_1+L_2)}{\partial r} = -\frac{1}{2}\left(\frac{V_p+V_w}{A_p-A_w}+(A_p-A_w)\right)$$

This formula tells us that discounting has a larger impact when ages at the perception of benefits and at payment of contributions are more distant from each other, as one could have expected, but also when there are larger variations of these two ages around their mean values. Numerically, if the lengths of active life and the retirement periods are respectively 40 and 20, then $V_w = 1600/12$ and $V_p = 400/12$, so that, with $A_p - A_w = 30$, leading to the semi-elasticity of about -18, i.e. a one percentage point increase of r reduces liabilities by 18%. This is roughly the order of magnitude obtained through simulations.

In the limit case of a stationary population where there would be no variability at all of these two ages, i.e. everybody gets a pension just at age A_p after having paid a one shot contribution at A_w, the total number of people with a liability would be proportional to $A_p - A_w$, and average liabilities per capita would lie in-between the value of p for people reaching age A_p and $pe^{(g-r)(A_p-A_w)}$ for those aged A_w currently paying their one shot contribution. In that case, scaling cohort size down to 1, global liabilities are approximately equal to :

$$p(A_p - A_c)e^{(g-r)(A_p-A_w)/2}$$

We directly retrieve formula $p(A_p - A_c)$ in the special case $r = g$ and the semi-elasticity of $-(A_p - A_w)/2$ with respect to r.

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