PRISME
A dynamic microsimulation model for the French pension scheme CNAV

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"Pour l'enfant, amoureux de cartes et d'estampes,
L'univers est égal à son vaste appétit.
Ah ! que le monde est grand à la clarté des lampes !
Aux yeux du souvenir que le monde est petit !"
(Charles Baudelaire)

Introduction
the genesis of microsimulation model *PRISME*

Before presenting the microsimulation model *PRISME* our team created, we feel necessary it to recall the institutional framework surrounding its birth in 2004.
Our employer, the so called *"régime général"*[general scheme] or "CNAV", is the main pay-as-you-go pension scheme in France. It covers private sector employees and manages about 12 million retired people and 17 million contributors (71% of active people), representing about half of Social Security liabilities..

Only 3% of people known by French welfare ever contribute to our scheme in their whole life. The *régime général* is part of numerous 1st pillar French pension schemes covering different kinds of people such as wage earners, craftsmen and storekeepers, liberal professions, public sector employees or other specific schemes contributors.
Pension formula is detailed in frame 1.

Wage earners contribute today on a basis of 16.65% of their gross wage, with a 1.7% contribution above the social security ceiling that levels up to €2,900 per month. The mean old age pension among new retired people amounts to €600, without accounting for pensions from complementary or other 1st pillar schemes. On the whole, retired people covered by French schemes earn about €1,100 a month.

Anticipating contributor stagnation and a boom in old age pensioners, the French government took some measures to significantly reduce pension schemes equilibrium deterioration. The last reform dates back to 2003. This reform was so precise technically speaking that projection models based on mean representative individuals and used up to 2003 became useless.
Our dynamic microsimulation model was created because of this reform, in order to evaluate global and individual consequences of past (and future) legislation changes. "Microsimulation" due to its initial 4 million people database, "dynamic" because of the number of 3-months periods projected (a 2050 temporal horizon). This model was developed under SAS environment.

Frame 1. Pension formula for private sector 1st pillar scheme

Old age pension relies on 3 terms : annual mean wage, pension rate and a ratio representing duration of insurance in our scheme.

$$Pension = Reference\ wage * Rate * \frac{career\ length\ in\ "Régime\ général"}{minimum\ career\ length\ in\ scheme}$$
$$(+\ possible\ differential\ corresponding\ to\ pension\ minimum)$$

In France, wage earners in private firms can retire from 60. Since 2004, some can retire from 56 in the case of a long career started very young.

Former nominal wages (truncated below the wage ceiling) are revaluated, following price index. The mean of the 25 best revaluated wages is then computed and is called the reference wage.

When retiring at 65 or more, in case of disability, or after minimal career duration under all schemes (from 40 to 41 years depending on generation) gives a full rate (i.e. 50%) and elects for a possible pension minimum (40% of retired perceive this minimum). Fall or bonus applies on the pension rate in case of, respectively, insufficient duration or work after full rate (+/- 5% per year).
Insurance duration within *régime général* is usually calculated in 3-month periods, because official durations are also expressed in 3-months. Gaining a quarter depends on wages : a certain wage amount (€1,742 for 2009) validates one quarter, for a maximum of 4 quarters per year.

The minimum career length in one scheme is up to 41 years for now.

Pensions are linked to price index. Under financial income conditions, *CNAV* also pays widow pensions, based on 54% of deceased people pension.

In the first part of our article, we present briefly how we sampled and completed our data before any projection. We also present the model architecture.

In the second part, we detail the different steps of *PRISME* modeling (demography, activity, wages, retirement decision, reversion). We focus on a key-module in pension scheme projection : retirement decision modeling.

In the third part, we show both the typical progress of our program under SAS environment and examples of dynamic microsimulation usefulness.

A- Sample, completion, architecture

1 Sampling method and completion

1.1 Sampling method

Initial data are administrative data, fed in real time (such as identity, careers, and retired people records) or individual and statistical data raised every 3-month. These statistical data gather much more information on the 12 million retired compared to administrative records (more precise kind of pensions, amounts, dates, insurance duration…). The problem is its limitation to the only *régime général* scheme, while other data concern people born from 1900 to 2008 and known by French welfare system (whether it is from illness, old age or family public insurance).

PRISME relies on a sample of one 20th, renewed every 2 years, or to be more precise a selection of 5 control keys randomly chosen among 97. These keys are coded on the two numbers that follow the *NIR*[4]. This sampling method allows keeping the panel between new extractions, enriched with new insured people corresponding to the selection criterion (births and immigrants). Data on retirement are actualized every 6-month (evolution of pensions, deceases…), for a better precision of short term forecasts.

Initial data table has as many observations as individuals, with more than 800 variables. Each individual is defined by an identifier (*NIR* is hidden due to anonymity protection) and data on demographic, career or retirement events.

<u>Demographic part</u> gathers general data (such as gender, year and quarter of birth, possible year and quarter of death), offspring data (number of children, year and quarter of child births for a maximum of 5 children) and possible immigrant status (country of birth, year and quarter of entry on French territory).

<u>Career part</u> gives information on early career (first activity age, end of schooling age), on activity report and the number of 3-months periods it gives, on annual gross wages.

<u>Retirement part</u> includes data necessary for retirement date decision and pension calculation, such as

- Number of 3-month periods accumulated as a wage earner in private firms or in other pension schemes, making a clear difference between contribution duration and other kinds of duration (due to children for instance) since last pension reform implies it,
- Mean annual wage (reference wage),
- Rate of pension,
- Bonus quarters...

For people that have already retired, date of retirement is recorded, and so are pension amounts (before and after minimum of pension) and other so called 'complementary benefits'.

[4] NIR or "Numéro d'Inscription au Répertoire (Répertoire national d'Identification des Personnes Physiques)" : identifier composed of 13 figures, so called "social security number", followed by a control key on 2 figures.

Among all these necessary data, some are lacking in available administrative or statistical data, for multiple reasons :

- Data imperfection, quality of feeding problems (around identification, financial incomes…)
- Data information given only after 55 (other scheme career, family composition…)
- Useless data for welfare system but essential for microsimulation (like end of schooling age)

The projection exercise can only start after a data completion step, as described below.

1.2 Completions

Completion differs from creating new observations linked to future births or immigrants. It aims at creating or completing variables, not at adding new lines to the table like projection does (*cf.* point 2).

Deceases completion

Our scheme knows of almost all the births at the age of one month for those born in France. We have data on immigrants when they gain access to welfare system. We also know every case of death of residents.
Nevertheless, some of the deceases are not recorded,

- either because it comes from people born and dead long ago,
- Or because it is due to former immigrants that left French territory, and for which death is not known.

For these reasons, we proceed to death completion for individuals born in France before 1946 and for those born abroad before 1980. We first calculate their age during their last year of presence, for employment, unemployment, illness, or retirement for example.
We then evaluate, by generation and gender, death probabilities for each age[5], knowing that the insured is alive at the age previously described. These probabilities are adjusted to take into account deceases already known and insured people surely alive.
At last, by comparison with a randomly distributed variable, the model determines the possible decease for the completion part. This death attributed is different from the death event simulated in projection (see architecture below).

End of schooling age

End of schooling age is important information for numerous events affecting insured people in projection. It concerns child arrivals, wage growth, transitions concerning employment, and mortality. This variable is missing in our scheme data. We attribute such an age for each individual concerned by projection with the help of wages they perceive in their early career.

Schematically, a strong wage increase before 30 is considered to be a signal of the end of schooling during the year preceding this increase. The rate of increase was calculated so that the distribution of end of schooling ages corresponds to the one declared by wage earners of private sector in an *INSEE* polling called "employment survey".

[5] From *INSEE* demographic tables

For insured people whose first annual wages do not show a sufficient increase to recognize a signal of end of schooling, or for those who do not have any wage before 30, end of schooling ages are half-randomly attributed so that global distribution respects "employment survey" conclusions, including all employed people.

Births completion

Familial characteristics such as number and age of women's children are indispensable elements for future old age pensions. They influence both careers (especially for women) and amounts of pensions.

In the initial data, offspring reached by each insured is integrated in the model, according to its personal characteristics.
Women offspring is estimated from individual characteristics (generation, country of birth, end of schooling age) and from career events (illness kind of events especially). These events allow determining eligible years for arrivals of children.
We determine, for each eligible year, a probability of having a child using logistic equations calculated by *INED*, on the basis of a national survey on family history (1999 "family survey").
Comparison with uniform randomly distributed variables will possibly create a child in one's career, with a precise date of birth.

We also give offspring to men, even if their careers (as shown by our studies) do not depend as much on children than women. Our method is more simple for men : only the number of children is calculated. Probability of having a child depends on possible information of offspring in administrative records and on observed distribution in the "family survey" cited above, according to the man's generation, country of birth and father's end of schooling age.

Careers completion

Some activity periods in other schemes and military periods are unknown to us.
Careers completion is in 3 parts :

- military periods,
- other schemes periods for people that were once wage earners of private firms,
- career completion for those totally unknown to our scheme.

Military periods completion for men between 18 and 30 is done using numbers given by the Ministry of Defense and data from people already retired for which we know military periods characteristics. We know the number of completions to be made from these data, and from age distribution and legal length of military services.
For each year and generation, we choose to attribute a military period to insured people having a lack of activity corresponding to the length of compulsory military service, until we reach the completion target.

For activity in other schemes of people we partially know the career, a sample of multi-scheme contributors (namely *EIC*) from *DREES*[6] and some logistical equations help.
Once again there are 3 steps : selection of multi-scheme people, choice of one kind of scheme and length. Each step has 3 parts. We first estimate equations coefficients from retired people

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[6] translation of "Direction of Research, Studies, Evaluation and Statistics", of Health and Sport Ministry

(for which we know the whole career). We estimate an answer variable for careers we have to complete. People are ranked due do this answer variable, and depending on the number of reports to be made, we complete their careers.

For people that never earned any wage in the private sector, we first choose those who have no career at all. Data from *EIC* allow to calculate ratio between :

- the number of those who have other schemes reports (by family of scheme) without any report in our scheme,
- and the number of people for which we have at least one kind of report.

We deduce from this ratio the number of activity reports by rule of three applications.

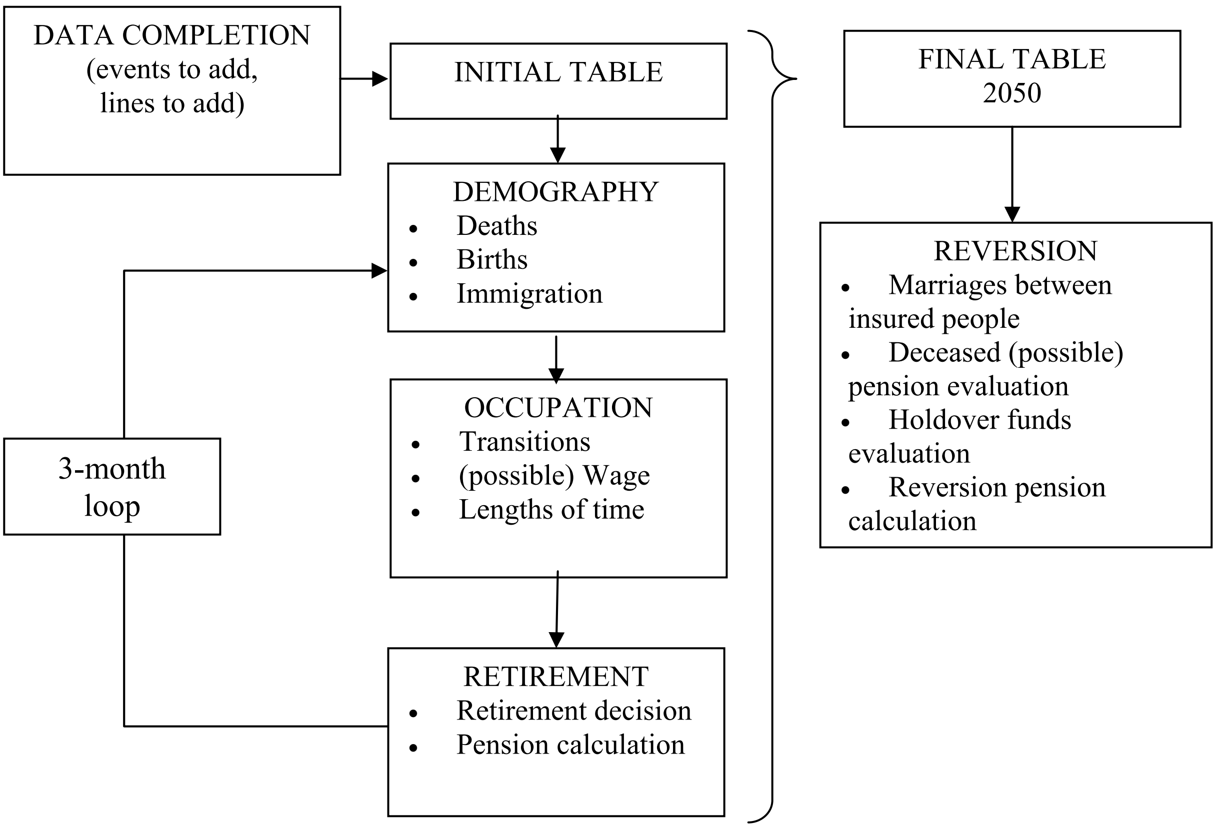
At last, some transverse adjustments are made so that the number of other scheme periods per year remains valid.

2 Projection organization

Once initial table set, preparation work is not over. It is necessary to fill all parameters needed, such as :

- Demographic hypothesis : choice of mortality table (to be chosen from several), of fertility rate, of immigration numbers, from now to 2050. Lines created for future births and immigrants are added to the initial table.
- Macroeconomic hypothesis for the next 50 years, like supposed mean wage growth and rate of unemployed. We have to verify for each year of projection that this rate is respected. The number of contributors from other schemes is also verified, once the number of working people is checked. Some adjustments are possibly made so to respect mean wage growth hypothesis.
- Legal environment hypothesis is chosen, like "before 1993 reform", "before 2003 reform" or "since last reform". Minimum pension index is specified, among other necessary amounts. Quite a big number of tables are memorized in SAS environment, corresponding to bonus rate, legal number of 3-months periods for full rate pension, etc. We will be more precise on the method we use to memorize such data later in this article.
- Finally, all logistic equations parameters or transition matrix parameters are put in SAS formats or memorized in macro-variable form, so to evaluate occurrence probabilities, for each event in *PRISME*. This implies that econometric tasks are made before projection.

PRISME model can be summed up using this diagram :



Each loop is detailed in C part.

B- Modeling (modules and sub modules)

This part of our work is aimed to present each modeling step. In a first part, we present new contributors addition to the initial table. The second part is about demographic events modeling. In the third part we present occupation and individual wages modeling. The fourth and fifth parts are about retirement decision and reversion. A focus will be made on this retirement decision module, which is a key module in any pension scheme model.

1 Addition of new contributors

One of the first steps is to create individuals that will appear in the future, either born in France or not.

Future births in France

The number of new insured people to add is calculated, per generation and gender, from births previsions made by *INSEE*. Sex ratio is based on past data (51.19% of male births).

Born abroad future contributors

Observations corresponding to people born abroad and coming on French territory during years of projection are added to the base, to take them into account as future contributors.

To estimate their numbers, we use what we know from people born abroad and having some occupation reports, whatever the kind of report, for the 10 last years before projection.

Flow of first reports is very similar to the official flow as estimated by *INED*[7], though both kind of people are not exactly the same : immigrants for periods over one year for INED, immigrants for any kind of jobs or appearance motive in our data.

Immigrant flow is estimated at 200,000 entries per year. These entries are equally distributed between men or women. Distribution by ages is the same as the one appearing in the immigrant part of the last general census in France (1999), for the years of 1997 and 1998.

We endow these immigrants an end of schooling age and a fertility rate from the same methods we apply to people born in France. As they may arrive in France with periods validated in foreign scheme, we also endow them some 3-month periods, depending on our observations on people born abroad and already retired.

[7] translation of National Institute of Demographic Studies.

2 Demographic event modeling

PRISME projection model is modeling two main demographic events : births and deaths.

2.1 Births modeling

A number of children and a birth calendar are allocated to women born in France between 15 and 49. It depends on logistic equations, according to time covered since end of schooling.

Women's first child is modeled differently from other possible brothers or sisters, as shown below (ESA standing for "time since the end of schooling age").

$$P\left(1^{st}\,birth\right) = \frac{1}{1+\exp\left[-(\alpha+\beta\,age+\gamma\,age^2+\delta\,age^3+\eta\,ESA+\vartheta\,ESA^2)\right]}$$

$$P\left(following\_births\right) = \frac{1}{1+\exp\left[\begin{array}{l}-(\alpha+\beta\,age+\gamma\,age^2+\delta\,age^3+\eta\,age\_youngest\\ +\vartheta\,age\_youngest^2+\omega\,age\_youngest^3+\phi\,age\_youngest^4)\end{array}\right]}$$

For instance, first birth probability is given by parameters listed below :

Table 2.1.1 – First birth annual probability

Parameters	ESA < 18	ESA > 17
Constant (α)	-14.7458	-57.9839
Woman age (β)	1.2729	5.069
(Woman age)² (γ)	-0.045	-0.1518
(Woman age)³ (δ)	0.00051	0.00148
Time since ESA (η)	0.2972	0.2185
(Time since ESA)² (θ)	-0.0145	-0.0122

These parameters are calculated with the help of *INED*, and from 1999 family survey. Numerous successions of parameters have been estimated, depending on fertility rates hypothesis. For now we take 1.9 child per woman as central hypothesis.

For each woman between 15 and 49, we estimate the probability she becomes a mother, depending on variables listed in table 2.1.1. If the hazard we draw is lower than this probability, we implement offspring by one child and give a birth date for this child.

Such equations are also applied to women born abroad. For years previous to the migration date, we consider births to be possible up to a year and a half before the entry on French territory.
To obtain higher fertility rates observed for women born abroad compared to women born in France, the end of schooling age taken into account is the lowest possible.

No child is allocated to men born in France : those born before projection start have a number of child at birth completion step, and those who will be born after projection beginning will not be retired before the end of projection. Men born abroad have children depending on their observed distribution per generation and number of children (as given by *INED*).

2.2 Death modeling

Disabled or unfit to work retired people have specific mortality rates, higher than those of "normal" retirees. Life expectancy at 60 differs by at least 5 years. Life expectancy at 60 of retired people is also higher than the one applying to over-all French population.
Overall retired people of our scheme have the same mortality rates than the one calculated by INSEE in France.
To be more precise in the modeling of death for retired people, we apply mortality rates by gender, age, year and kind of pension (normal versus unfit or disabled). Such rates are observed till 2005 and extended until 2050, following INSEE mortality tendency.

Insured not yet retired follow mortality rates, projected by INSEE from now to 2050.

Each year we compare this mortality rate to the hazard we draw for each people in our model. If the hazard is lower, insured dies and never enters future program loops, excepted reversion.

Deaths are attributed not only to a year but also to a quarter, so to respect observed death seasonality and improve short term previsions. For instance, we have about 22% more deaths in January than in June.

3 Activity and wage modeling

Following 3-months steps, we draw a future, whether in terms of kind of activity or in wage levels in case of occupation in private firms.

3.1 Activity modeling

Transition module is the modeling of activity status for each individual and each quarter in projection. It results in halving people between working and non-working. Inside the first category, several cases are possible for people between 14 and 69 :

- wage earners in private firms,
- wage earners in some precise schemes (wage earners in farms, craftsmen, storekeepers), called "near schemes"
- wage earners in other schemes (public scheme for example), called "distant schemes"
- unemployment,
- sick leave,
- unfit to work or disabled
- other situations resulting in no quarter validated

For now, a transition matrix is used to modelize changes between these positions, from time to time. It is based on past events (from 2001 to 2003), depending on gender, age range, country of birth and, inevitably, kind of event in previous quarter. It gives probabilities corresponding to each kind of movements between two 3-month periods.

Brackets of age range are connected to end of schooling age, to take into account observed increase in studies duration.

As an example, for a man born in France who finished his studies for a few years and outgoing from a status of wage earner in a private firm has probabilities up to :

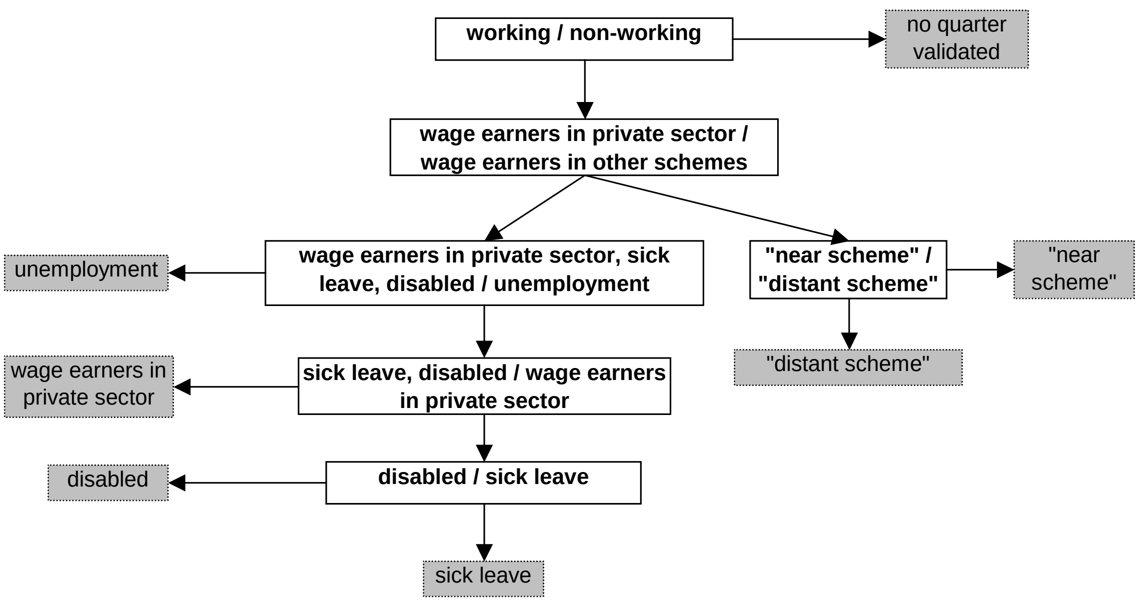
- 93% to stay in the same position (though he can move to another job still in private firms),
- 3% to validate nothing during the next 3-month period,
- 3% to report an unemployment status,
- less than 1% of sick leave,
- about 1/1000 to change his kind of job (position 2 or 3)
- almost 0% to become disabled.

In projection, these transition probabilities are not rigidly applied. We have the constraint to follow a macroeconomic path usually different from the one observed between 2001 and 2003. This is the reason why we had to implement 5 kinds of wedges, on :

- numbers unemployed,
- contributors (our scheme)
- contributors (near schemes)
- contributors (distant schemes)
- disabled

However, we want to improve our model, especially to respect individual trajectories in a more precise way than transition matrix does. We have thus tried to build a set of logistic equations, which should help to be more precise on individual effects. This set gathers 96 equations, depending on gender, distance to end of schooling age and country of birth. Observations are made between 2001 and 2003. Independent variables change according to the kind of transition, age groups, gender and country of birth.

Logistic equations chain is as follows :



<u>reading guide</u> : white box stand for observed and tested situations. Grey box are resulting 3-month periods.

The comparison between hazard drawn and status probability can lead to two situations, either a new status or further tests (sick leave vs disabled for instance), until we end up with a precise status for each individual and each quarter.
Though more precise than transition matrix, it is also more difficult to handle. There is a great dependency on initial conditions. It is necessary to monitor equations chain and numbers at each step, otherwise it could end up with omnipresence of a precise kind of period.

For instance, take a look at the logistic equation used to determine out of job people. If its modeling is not adequate, inactive people could be too numerous or too small, in an increasing manner as time goes by. This could occur even in the case following logistic equations are valid.

Apart from these difficulties, processing time increases tenfold when using such a set of equations, and wedging is much more difficult too. These are the reasons why, for now, *PRISME* continues working with transition matrix in place of logistic equations.

3.2 Wages modeling

Wages module allows to allocate annual wages to individual whose 3-month position is corresponding. It is an important task, as it determines both overall contributions and, partially, future old age pensions.

Estimated wage is an annual theoretical wage, and may be reduced in proportion of employment duration (in quarters) within the year so to give annual maximum wage. This wage is used for comparison to macroeconomic growth path hypothesis.

Wage estimation uses 4 log-linearized OLS regressions inspired by Mincer modeling, depending on gender and situations before or after end of schooling. Dependent variables are wages from 1999 to 2004 coming from our sample.

Equations testing is as follows :

$$\ln(w_{jt}) = \alpha + X_{jt}\beta + u_j \qquad \forall j, t \ \text{(individual } j\text{, time } t\text{)}$$

where $w_{j,t}$ is wage at time t for individual j, α is the constant term and $X_{j,t}$ the independent variables vector. Wage stands for part-time or full-time worker together.

For wages before end of schooling, we use current age, square of current age and a dummy representing individual presence in t-1[8].

Once school is over, independent variables are end of schooling age, market labor past experience, square of this experience, and dummies representing recent unemployment, unemployment at least once during career, the fact to be disabled once, presence in t-1 and children number[9].

[8] This dummy aims at taking into account selection effects due to the kind of panel used.
[9] Only for women.

Because wage gathers both part-time and full-time workers, explanatory power of such a model is weaker than usual gains equations estimations, which applies for full-time workers only. Parameters coefficients are very close to those seen in studies on French data, though.

Decile structure of gaps between observed wage and estimated wage for 2004 is reproduced in projection. We do so to keep wage variety, within families of individuals defined by gender, country of birth and age bracket. In projection, individuals used for estimation keep the residual value for their whole career. For other individuals (no wage in 2004, wages during studies), this residual is normed.

4 Retirement decision module

Retirement module determines at each time step if an individual decides to retire, in which case we allocate a year and a quarter of retirement for this observation.

Insured get into this program loop only from 56 to 69. Some people have no job in private firms, no unemployment periods, no sick leaves in our scheme. In this case, fictive retirement ages are given at 60 or 65, depending on the kind of schemes they knew during their careers. We want here to exclude them from program loops, so to reduce processing time.

For *régime général* recipients, retirement decision module is divided in parts corresponding to their age.

- Unclaimed pensions
- Retirement before 60
- Retirement for unfit to work
- Retirement from 60 to 70.

Speaking about programming, each of these parts is called by a sub-macro placed in the main program. These sub-macro are called when non-retired people age is inside the corresponding age brackets.

Retirement decision modeling relies on logistic equations. To estimate these equations, we built a table gathering retired and non-retired people from our sample. We chose to complete some data for non-retired people, instead of taking older generations with maximum information. The goal here is to start projections with the most recent comportments embodied in parameters values.

4.1 Unclaimed pensions

Some of our insured do not claim for their pension. It might come from people continuing working long after 60 and dying before they retire. It might also come from people who forgot their first jobs (at 16 or 17) in our scheme before a long career in other schemes. A big part of these unclaimed pensions comes from former immigrants who went back to their country of birth once old.

In our programming, unclaimed statement is decided during the individual quarter of 69. We use two logistic equations, one by gender. These equations are estimated from a sample of non-retired people over 68, born between 1925 and 1927. Independent variables are *régime* *général* insurance duration, country of birth, reference wage, and dummies representing inactivity just before 69 or the fact that this individual has multiple schemes rights.

In our model mecanisms, if insured is 69 without being recipient, a sub-macro is called. It aims at testing for its unclaimed property, with usual comparison between calculated probability and uniform hazard draw. For every hazard below probability, pension is to be unclaimed. Otherwise, insured is considered retired at 69.

4.2 Early retirement (or retirement before 60).

Since 2004, one can retire before 60 after early and long careers. For instance, if one spent 42 years working and began working at 16, early retirement is possible from 58. It represents around one sixth of all retirements between 2004 and 2008.
Retirement before 60 has to be precisely conceptualized, because of its influence on short-run budget control. Conditions has recently been hardened, resulting in early retirement decline.
If insured is eligible to an early retirement, main program calls a sub-macro where probability of retirement is calculated. Logistic equations are previously tested in a data table gathering early retired and eligible insured not retired. Modeling is done by precise age (to the quarter) and by gender, which implies 32 equations.
Explanatory variables are time spent since eligibility, employment in last quarter, insurance duration in our scheme, a dummy representing unemployment in the last year, and reference wage. Once again, probability based on logistic equation coefficients is compared to a hazard. If this random variable is lower than calculated probabity, individual retires. Otherwise nothing happens and program gets out from early retirement sub-macro.
In the case of early retirement, program allocates a retirement date and calls 3 sub-macros. The first one updates cumulated durations, the second one updates wage data, while the third one calculate old age pension, before going back to main program.

4.3 Retirement from 60

This sub-module is in 2 parts. As a first step, individual not retired at 60 possibly becomes unfit to work for an immediate retirement. From then and in the case he is not declared unfit to work, "normal" retirement decision is tested every 3-months period.

a) Unfit to work

Unfit to work retirements are simulated only for less than 65, and this event causes immediate retirement with a minimum retirement age at 60.
Six logistic equations (by gender and age brackets such as 60, 60.25, 60.5 and more) are tested. Independent variables are legal full rate duration, insurance duration, reference wage, employment status, country of birth, end of schooling age, dummies representing unemployment or sick leave in the last year or the fact that this individual has multiple schemes rights. It finally appears that these explanatory variables fit well to presupposed low wages and job insecurity of disabled people.
Comparison between random variable draw and calculated probability decides whether insured is unfit to work (and retires) or not. If he retires, normal retirement loop is called.

b) Normal retirements from 60

In this sub-macro, we first isolate non-retired people concerned by unclaimed pensions and unfit to work pensions so that they automatically retire. For other insured, retirement probability is calculated with the help of several logistic equations which deserve a special focus.
Not less than 46 equations are estimated, by gender and for each age (to the quarter) between 60 and 65.25 (and one for higher ages). Each of these equations retains different explanatory variables vectors. It is done so in an attempt to apply the best specification, measured by Akaike and Schwartz criteria and concordant pairs rate.
We present here two examples of such estimated equations, using PROC LOGISTIC under SAS environment.
The first one deals with men retirement at 60.

```
proc logistic data=m60
      (where=(precise_age=60)) descending outest=coef_mret1;
by precise_age;
class dist_to_frate (ref='3') emp2 (ref='0') t (ref='4') b_country
(ref='1')/ param=ref;
model retire= dist_to_frate emp2 3month_valid multi_sch unempl1 sick_leave1
job_to_valid end_studies b_country ref_wage / selection=stepwise ;
title' mret1 ';
run;
```

Variable named *retire* is a binary variable that equals 1 when insured retires during present quarter, or 0 in the contrary. SAS is asked to test for the case *retire* equals 1 by using 'Descending' option. On 'class' line are specified discrete variables, with reference modality in parentheses. Explanatory variables are listed below.

- *dist_to_frate* expresses in 3-month is the difference between legal duration of full rate eligibility and all-schemes individual insurance duration, expressed in 5 ranges : [<0] ; 0 ; [1-4] ;[5-19] ;[>=20].
- *emp2* has three positions : '0' for unemployed, '1' for wage earners in private firms, '2' for other jobs
- *3month_valid* is (continuous) insurance duration under 'régime général'
- *multi_sch* is a binary variable representing insured known by numerous pension scheme. It is set to 1 if insured has validated quarters in other schemes,
- *unempl1* and *sick_leave1* are dummies representing unemployment or sick leave in the last year
- *job_to_valid* is overall job duration to insurance duration ratio,
- *end_studies* is end of schooling age as estimated in *PRISME*,
- *b_country* is equal to ‘1’ for insured born in France or ‘2’ otherwise,
- *ref_wage* is the reference wage as defined in introduction, but calculated among the 30 best annual capped and revaluated wages (instead of 25).

This modeling is strongly built in reference to full rate distance. It was prefered to pure overall duration, because legal duration is to increase in the future (as mentioned in 2003 reform). *Dist_to_frate* is not continuous because it appears it evolves non-linear relationship to retirement decision, especially for people whose distance is negative as they might be interested to stay in activity and to gain pension bonus.

Following equation is estimated for women between 65.5 and 68.75 still non-retired at 65 (last age category). It represents about 20,000 retirements (men and women together) in 2005 (3.5% of overall retirement flow). Despite our sample size and because women tend to retire mainly before 65, it appeared impossible to test this equation for each precise age between 65 and 69. Furthermore, we wanted to simplify our tests concerning this category that does not carry much weight on overall expenses.

```
proc logistic data=w65
      (where=(precise_age>=65.5)) descending outest=coef_wret23;
class dist_to_frate (ref='0') t (ref='1') emp2 (ref='0') b_country
(ref='1')/ param=ref;
model retire=frate v_rg precise_age job_to_val t emp2 multi_sch end_studies
/ selection=stepwise;
title' wret23 ';
run;
```

In this logistic equation, new variables appear :

- *frate* is a dummy corresponding to full rate eligibility due to insurance duration[10],
- *precise_age* is age to the quarter, considered to be continuous.

People over 65 and not retired yet is quite heterogeneous. They are mainly inactive and gathers in the mean low insurance durations. Some of them will end up in unclaimed pensions category. This is why activity or multi-schemes presence variables are determinant in the choice to retire or not.

Table 1. Predictive performance of logistic equations for retirements over 60

	Matching rate	Sensitivity	Specificity
Men	92.2%	37.5%	95.8%
Women	93.2%	40.0%	96.4%
Together	92.7%	38.7%	96.1%

In the last table, we can see that matching rate is about 93%, with a sensitivity of 39% and a specificity of 96%. It means we may have some problems identifying exactly who retires in the 3-month period (mainly because few people are concerned), but we do not make big mistakes among those who decide not to retire in the present quarter.

When programming retirement decision, no less than 46 logistic equations are used for normal retirements between 60 and 69. As in other modules, probabilities calculated using equations coefficients are compared to random draws from a uniform distribution. In case the former of the two is higher, event occurs and people is supposed to retire. Durations and wages (especially for last career year) are then finely calculated, and pension is estimated.

5 Reversion modeling

French pension legislation allocates widows' pensions when spouses former wage earners decease, under financial income condition. Widow's pension levels up to 54% of the deceased old age pension he(she) would have or he(she) had.

PRISME has a reversion sub-module called after old age pensions calculation.

[10] In the present example, everybody is eligible to full rate because of their age. This discrete variable has only 2 groups of values.

People already recipient of widow's pension at the starting point of projection keep the same pension until their death. For people concerned by new widows' pensions, we had to define potential recipients.

Because our initial data do not comprise couples connections, we had to create marriages between individuals of our sample[11]. First hypothesis, we marry from 90% (older generations) to 75% (from 1965 generation) people of our sample (included future births and immigrants). Almost 90% of 50 years old are married (*INSEE*).

Marriage consists in matching two insured of the opposite sex, constrained by two distributions : age differences and end of schooling age gaps between married. Both of these differences distributions are calculated on the basis of *INED* data from family survey.

In our program, men and women are gathered and sorted. Women have probabilities to choose husbands corresponding to certain age differences and school leaving age differences (3 groups for each constraint). Comparison with random draws from a uniform distribution decides wheter marriage happens or not, until we reach marriage rate objective corresponding to this kind of union. Remaining singles are put back and possibly selected again for a new configuration based on age differences and end of schooling age differences.
Different combinations of age differences and school leaving age differences have been tested to comply with family survey results.

Once these marriages are done, projection goes along and deaths occur, so widows appear in our model.

In a second step, we evaluate possible widow's pension based on own rights and ex-spouse rights. We estimate financial incomes, because only widows whose income stays under a certain threshold can benefit from *régime général* reversion. We thus have to estimate wages, pensions, patrimony incomes and, possibly, new spouse incomes in case of new marriage.
For active people we estimate occupation income (or replacement of occupation income) from calculated wages in private sector, by gender and age.
For retired people we estimate all-schemes pension (which we know only our scheme's part), and patrimony incomes. All-schemes pension is based on our pension, schemes specific career durations and results from inter-scheme sample (*EIR* survey[12], from *DREES*). Patrimony incomes are evaluated from INSEE or other research agencies studies, linking pension to such incomes :

- for pensions under 7th decile, we consider people to have no patrimony incomes,
- for pension between the 7th and 9th decile, patrimony incomes amounts to 25% of pension,
- for higher pensions, patrimony incomes adds 50% of these pensions to widow incomes.

Once defined people eligible to reversion (i.e. widows alive in current period and whose income is below a certain threshold), we calculate for each year of projection the amount of widows pensions.

[11] There are no spouses outside of our initial data, so no widows of people unknown to french welfare. Widows from abroad are kind of "replaced" by widows living in France.
[12] EIR is a 4-year sample based on data given by almost all french mandatory pension schemes. It allows to piece together overall retired pension.

C- Typical progress and examples of dynamic microsimulation usefulness

1 Typical progress

PRISME model requires important computing resources. It is executed on an Unix server, a quadri-processors server having a random access memory of 8 Go. This server is connected with bays of storage of a total capacity of 2.4 To.

PRISME is completely developed under SAS macro language. It is composed of 2 main macros (one for the old age pension estimation and one for the widow pension estimation) and of 22 sub-macros. In its current version, PRISME represents approximately 6,200 lines of program.

The macros are divided into 4 topics:
- Demography: 5 (births, immigration,…);
- Career: 6 (transitions, wages, insurance periods,…);
- Pension: 7 (disabled people, retirement decision, old age pension calculation,…);
- Reversion: 4 (financial income, widow's pension calculation,…).

PRISME requires many computing resources. An optimization of both the programming and the typical progress is necessary to obtain acceptable computation times. These optimizations deal with 4 axes:

- Data reading and writing control : one year of career historical is needed in order to estimate the events used in the old age pension calculation. To avoid reading and writing of a great amount of information that are useless to the projection, the career data relative to the previous year are stored in a different table at the end of every year of projection. At the end of projection, all the storage tables are matched in order to obtain a table containing the wholeness estimated careers.

- Use of random numbers : every event (birth, death, career transition, retirement decision) is determined by the comparison between a probability (logit or probability matrix) and a random number. There are as many random numbers as estimated events (for instance, 8 billion events can be estimated according to the size of our sample).
  In order to keep the same individual randomly distributed variable for each projection and simulation (to eliminate the only unpredictable effects in the analysis of the variants), and due to the significant amount of random number (potentially 8 billion), they are generated thanks to seeds and SAS ranuni routine (random number drawing from an uniform distribution): from an unique seed, ranuni will generate the same series of random numbers.
  Under PRISME, individuals ranking are created in which the order of the individuals is identical whatever the variant (in particular demographic variant, that can change the number of individuals).

- Formats’ creation : during the projection, for every event, the modelling requires scale data (social security ceiling, minimum amount of old age pension, full rate, etc.) and data set up before projection (probability matrix, logit coefficients, etc.).
  These data are stored in independent SAS tables. We use formats to appeal to these data. It allows for significant time saving in running the program and also an easier carrying out.
  PRISME uses more than 240 formats. All scales, logit coefficients etc… are store in formats that are called thanks to the SAS input fonction.

- MP-connect use : a SAS task (for example a DATA stage) only runs on 1 processor. Thus, the model basically written would use only 25 % of the Unix server power (quadri-processors). To remedy this problem, the model had been written to be executed simultaneously on 2 processors: the population is distributed every year between people aged less than 50 years and people aged more than 50 years. This is the very principle of MP-connect (MP for multi-processors): inside the main Unix session (launch of the model), N sub-sessiond are created. Treatments are distributed between the sub-sessions and are executed simultaneously on N processors under Unix environment.

When projections are run, several parameters are filled in. These parameters, for old age pension estimation, are integrated into the main macro call.
The modifiable parameters are, among others, the following ones:
- the number of the projection which allows to change the series of the generated random numbers and thus to measure the sensibility of the projection to them (from 1 to 5),
- the fertility rate (1.5 ; 1.8 ; 1.9 ; 2.1),
- the immigration hypothesis (weak, average, high),
- the sampling rate selected (1/20th, 1/100th, 1/1000th, 1/10000th),
- the year of the beginning of projection,
- the year of the end of projection,
- the legislation chosen (Balladur = legislation after the 1993 reform but without the 2003 reform; Fillon = legislation after the 2003 reform; Without = legislation before the 1993 reform),
- the mortality hypothesis (insee = INSEE mortality quotients applied to everybody; cnav = INSEE mortality quotients applied to the not pensioners and CNAV mortality quotients applied to the pensioners).

In annex we present a diagram illustrating the model mechanisms in SAS language.

Parameters of widows pensions estimation are integrated into the main macro call. These parameters are, among others, the following ones:
- the resources ceiling for a single person,
- the minimum of reversion pension.

Currently the time of computation for the one 20th sample is around five hours. In the one 100th sample it is approximately of one hour.

At the end of the projection, automatic results are executed. Some aggregate indicators are calculated dealing with the retired people stock and flow, such as the average old age

pensions, the overall old age pension paid and the number of retirements. These indicators can be declined by gender, age, type of pension, year of retirement, etc…
Automatic results concerning the careers in projection are also used.

Regarding the widow pension estimation, the output file contains also by year and by gender, stock (stock of the year, beneficiaries of less than 55 years old, additional advantages…) and flow (entering, going out, beneficiaries of less than 55 years old…) indicators.

2 Results – central scenario vs miminum retirement age postponing

2.1 Results –central scenario

We present now some results achieved in 2007 for the Conseil d'Orientation des Retraites (COR)[13]. For these projections, we applied various hypothesis, even if we only show here central scenario results. Main hypothesis are a decrease in unemployment rate until 2015 (4.5% from 2015 to 2050) and a steady wage growth (1.7% per year).

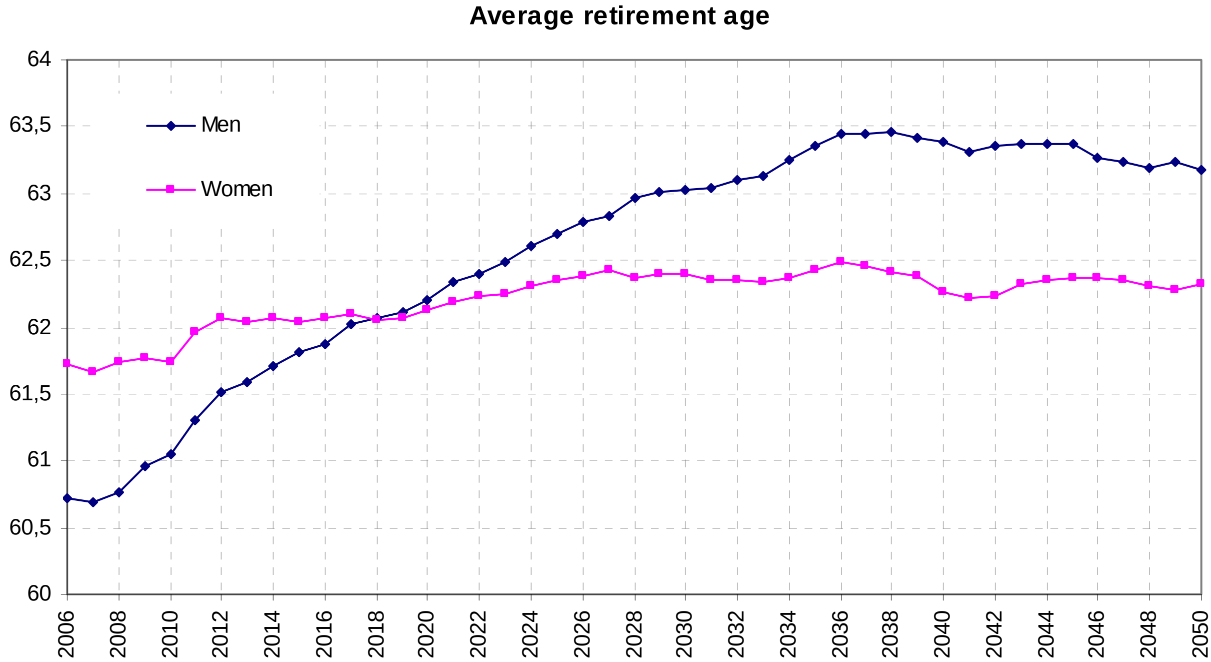
a) « Technical » CNAV balance

So called technical CNAV balance is the difference between contributions including some transfers and expenses (mainly old age pensions).
From 2006 to 2050, overall contributions would grow from €70,000 million to €160,000 million, while expenses would more than treble, due to retirees numbers and mean pension increases.
This explains why our scheme would get unbalanced as time goes by, reaching a deficit of about €45,000 million in 2050 (28% of contributions), without any reforms.

b) Average retirement age

As a central scenario, *COR* thought new conditions of (higher) bonus and (lower) fall of pension rates would encourage men to postpone their retirement date by 0.6 year in average, and women to anticipate theirs by 0.3 year. These hypothesis were implemented in *PRISME* retirement module, and explain partially why trends in mean average retirement ages varies between men and women. Other explanation is to be found in women's progressive participation on labor market as time goes by.

[13] The Conseil d'orientation des retraites ("Pensions Advisory Council") is a permanent body which brings together members of Parliament, representatives of the social partners, experts, and representatives of the State. Its main purposes are to monitor the French retirement system and to put forward recommendations for public policy concerning retirement, on the basis of expertise and consultation with all the partners involved.



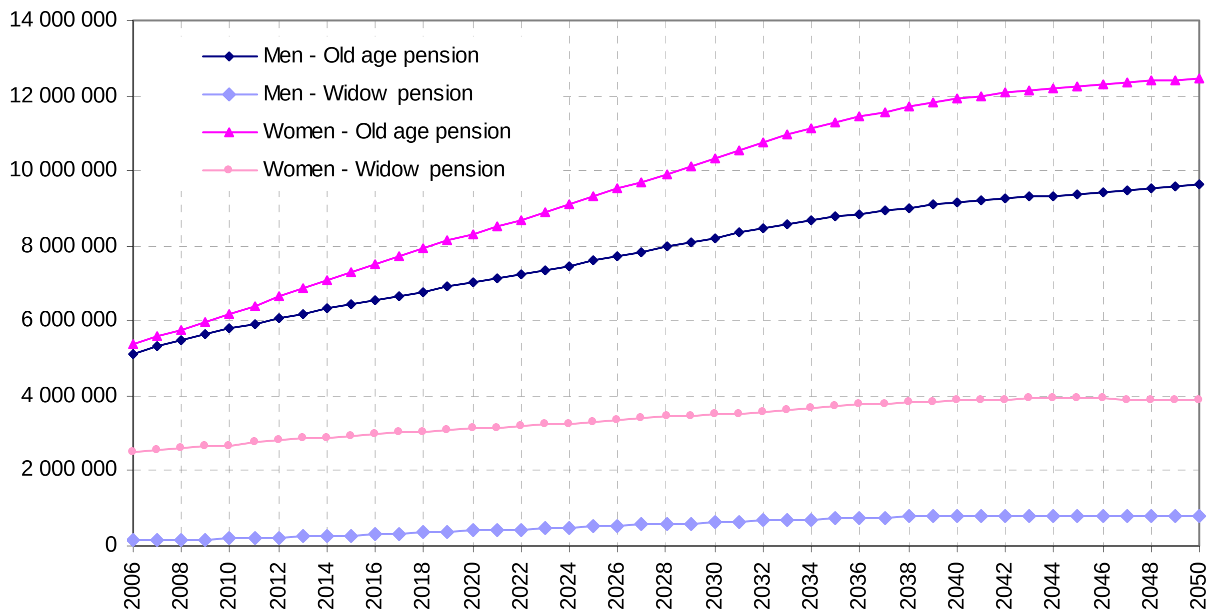
c) Annual average pension of new retirees

The annual mean old age pension of new retirees increases by 66% for men and by 75% for women (from 2006 to 2050). Widows' pension increases by 39% for men and 28% for women on the same period. This is due to mean wage increase and insurance duration (essentially for women).

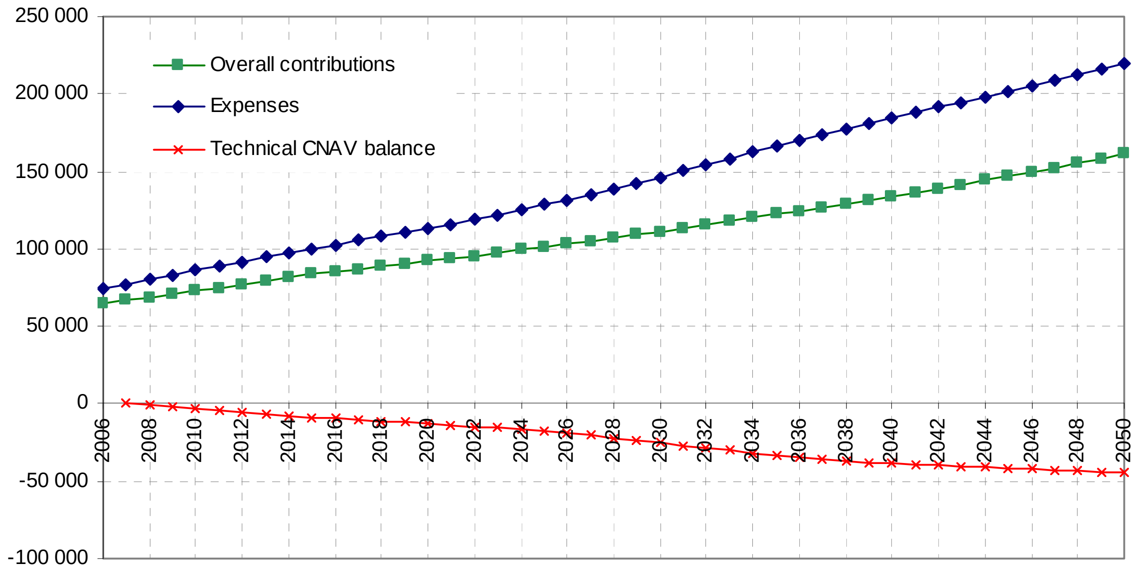
d) Retirees

From nowadays to 2050, old age pensioners numbers will double for men and more than double for women. Widows' pensioners will increase slowly until 2040.

Retired people



Technical CNAV balance *(M€)*



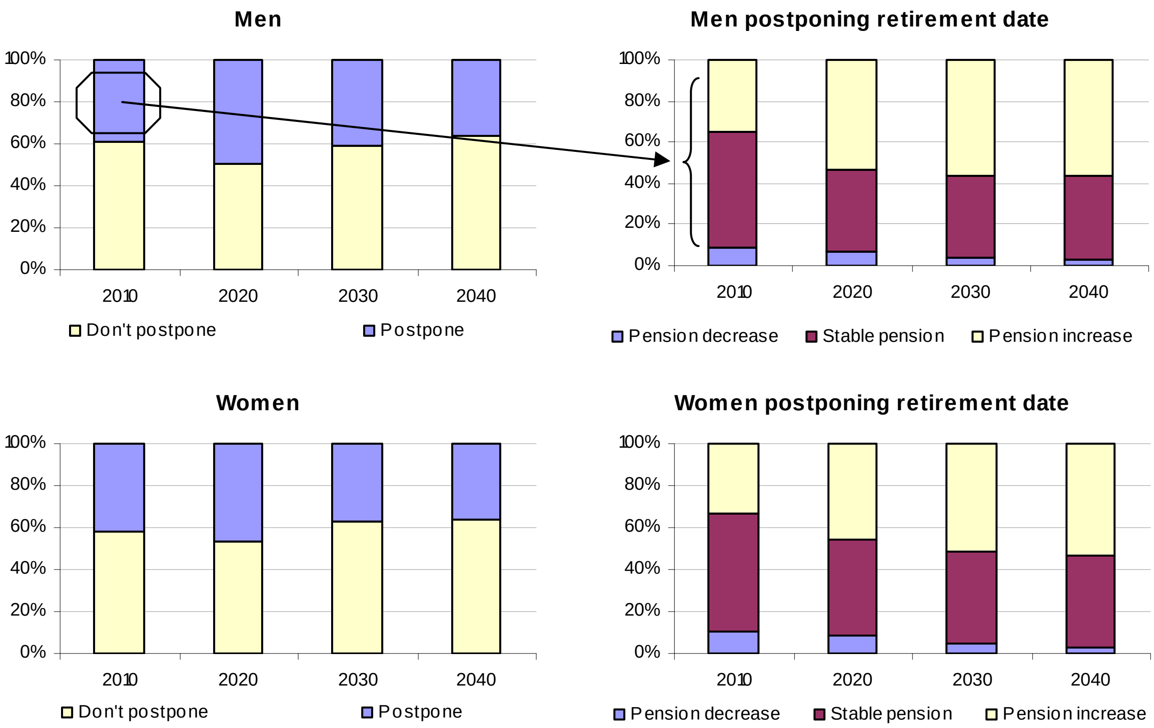
2.2 Simulation of minimum age of retirement shift from 60 to 61[14]

PRISME is also used for some simulations based on law changes, whichever agency calls for it (COR, Treasury department, Social services).
One of these simulations was based on a shift of the minimum retirement age from 60 to 61 (by a quarter per year between 2009 and 2012).

Several precise hypothesis were necessary :
- Early retirements (before 60) unchanged,
- legislation of retirements at 59 applied to retirements between 60 and the new limit,
- age shift applied also to people unfit to work or disabled.

a) Rate of people concerned

Each year, between a third and a half of insured would delay their retirement. Almost half of those who shift the retirement date would have a better amount of pension, due to better careers.



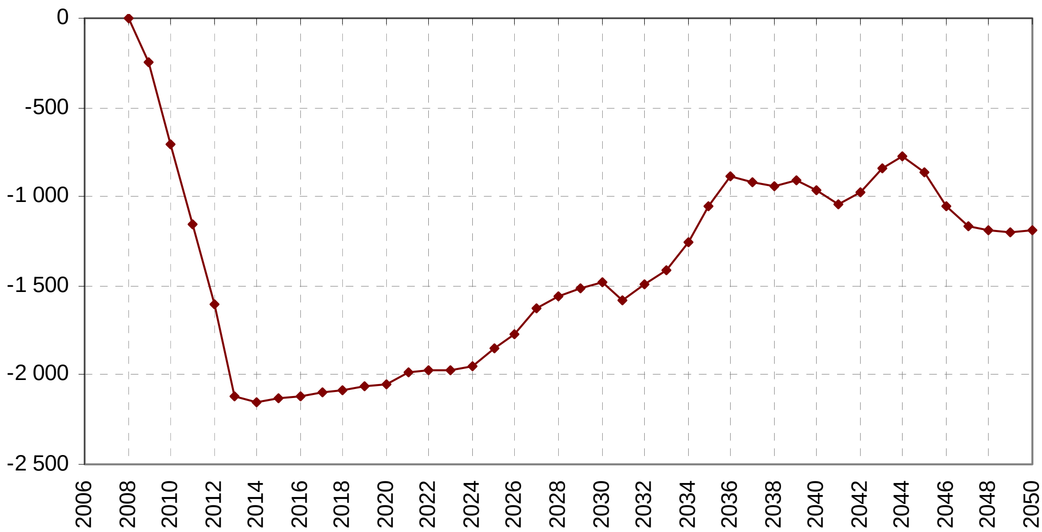
b) Influence of retirement age shift on overall expenses

Retirement age due to legal age shift would reduce expenses by nearly €2 billion in 2020. These gains would reduce starting from 2025 because of natural increases in average

[14] Concerning old age pensions. Only slight changes on widows pensions in theory.

pensions. The reason lies in the fact that delaying retirement make careers longer, and on average pension rates and reference wages higher.

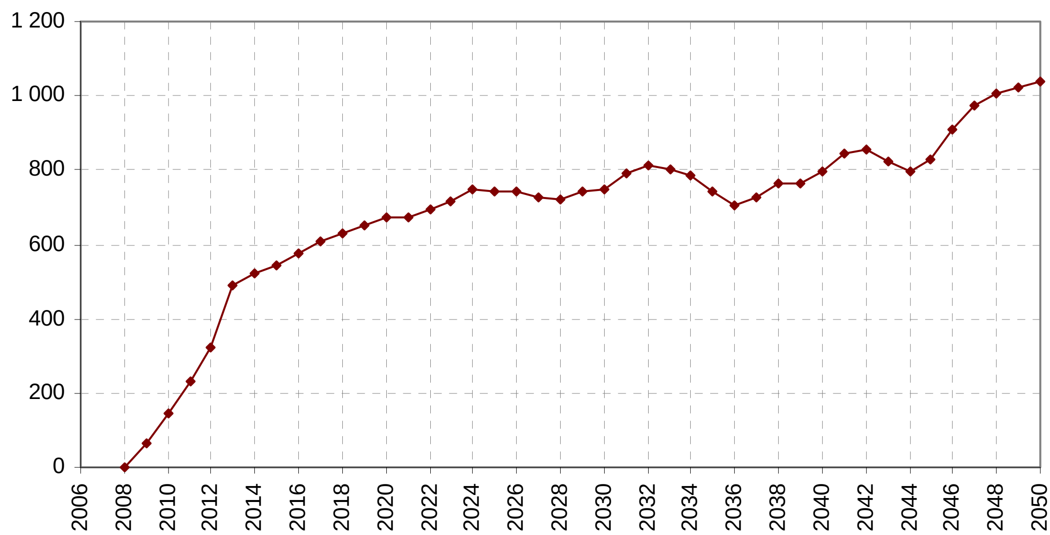
Lower expenses due to retirement age postponing *(M€2006)*



c) Influence of retirement age shift on overall contributions

Shifting minimum age induces an increase in effective average age of retirement. When retirees shift their retirement date, we made the hypothesis that they would stay employed if they have a job. So speaking about overall contributions, our scheme would gain about €700 million more in 2020 and €1.7 billion in 2050.

Additional contributions *(M€2006)*



d) Overall financial effect

This kind of new legislation would allow the *régime général* to have a better balance, earning €2.7 billion in 2020 and about €2.2 billion in 2050.

Conclusion – *PRISME* in the future

PRISME model answers regularly to potential pension reforms asked by different French agencies. This model is used as short terme prevision tool as well as financial projection model on long periods. Short term uses imply repeated updates and annual framing that might change long term results, so carrying out both sometimes appears difficult.

It is even used for radical changes in the functionning of the scheme itself, in the case of transition to a notional defined contribution scheme for instance. It proved to be useful to assess reforms at the intersection of health insurance, family allowance and pension scheme.

PRISME has become a reference in the process of continuous reform assessment since 2003. Some more articles on different kinds of simulations will probably complete in the future this presentation.

Appendix

The diagram presented below illustrate the model mechanical. It underlines the use, in our programming, of *macros* (main program external instructions blocks), of *symget* functions (recovering *macrovariables* functions), and of *formats* (data stored in independent SAS tables).
These functions allow for significant time saving in running the program and also an easier carrying out, as underlined in C part.

Call of the "creation of births lines" macro, according to births forecasts made by INSEE and sampling rate (%creat_nais_an)

```
%if (&fin.-14)>=&an_ech. %then %creat_nais_an;
```

Call of the "creation of immigation lines" macro, according to forecasts of immigrant flows and sampling rate

Call of the "calculation of the number of immigrants children" macro, in order to allocate the number of children born before their arrival on the French territory, according to the logit coefficients :

```
%if &fin.>=&an_ech. %then %do;
   %creat_immig_an;
   %creat_immig_nais_valid_an;
%end;
```

YEARLY LOOP

Table *youth* (generations under 14)

Call of the "End of schooling age calculation" macro, from the results of the INSEE "employment survey"

```
%if &an.=&deb. %then %afe_an;
```

Calculation of the date of death, from the mortality probabilities calculated on the basis of INSEE mortality projection, and according to the noticed seasonality; mortality probabilities recovered thanks to the use of *symget* instruction :

```
if alea<input(symget('dc'!!sexe!!left(put(age,3.))),7.5)) then do;
   an_deces=&an.;
   trim_deces=
      1*(0.00<=
      (alea/input(symget('dc'!!sexe!!left(put(age,3.))),7.5)))<0.266)+
      2*(0.266<=
      (alea/(input(symget('dc'!!sexe!!left(put(age,3.))),7.5)))<0.507)+
      3*(0.507<=
      (alea/(input(symget('dc'!!sexe!!left(put(age,3.))),7.5)))<0.743)+
      4*(0.743<=
      (alea/(input(symget('dc'!!sexe!!left(put(age,3.))),7.5)))<1.00);
end;
```

Table *working population 1* (generations in age to work, between 14 and 49)

Calculation of possible deaths (see young people)

Call of the "births calculation" macro, in order to allocate, if necessary, women offspring according to logistic regression coefficients:

```
if sexe ='2' and max(15,fin_etud)<=age<50 and nb_enf<5 and &an.>(&an_ech.-
2) and (an_deces=. or an_deces>&an.) then do;
   if nb_enf=. then nb_enf=0;
   %naissances_an;
end;
```

QUATERLY LOOP

Simulation of activity report and number of 3-months insurance periods

Call of the "wages" macro, in order to allocate annual wages to individuals whose 3-month position is corresponding, according to wages observed in the past

```
...
if trim=4 then %salaires_an;
```

Call of the "insurance period update" macro;

Call of the "best wages uptade" macro, for the calculation of the reference wage :

```
if (an_deces=. or an_deces>=&an.) and an_entree<=&an.
and an_ej=. and prem_rep^=. and age>=prem_rep then do;
   %maj_cumuls_an(tr=4) ;
   %maj_sal_max_an ;
end;
```

Table *working population 2* (generations in age to work, between 50 and 70)

Calculation of possible deaths : same as young people, except application of our estimated mortality probabilities by kind of old age pension (normal, unfit, ex-disabled people)

QUATERLY LOOP

Simulation of activity report and number of 3-months insurance periods

Call of the "wages" macro (same as for working population 1)

Call of the "insurance period update" macro (same as for working population 1)

Call of the "unclaimed pensions" macro, in order to remove them from the loop "retirement decision"

```
   if %if &retro_dep.=0 %then &an. >= &an_ech. and ;
   categ='' and agex=65 and trim_nais=trim then %non_reclames;
```

Call of the "Retirement decision" macro, in order to allocate if necessary retirement date, from calculated logits

Call of the "amount of pension calculation" macro, for new retirees; full rate duration recovered thanks to a format call (&liq.taux.) :

```
   if an_ej=. and agex>=60 then do;
      if categ='' and 60<=agex<65 then %inaptitude;
```

```
        %if &departs.=tx_plein %then %do;    /* Départs taux plein */

           if an_ej=. and (valid_tot_tr>=input(put(generation,&liq.tx.),3.)
           or agex=65 or categ^='') then do;

              an_ej=&an.; trim_ej=trim;
              %maj_cumuls_an(tr=(trim-1));
              %salaires_an;
              %calcul_pension_an;
           end;
        %end;
        %else %do; /* Départs avec probabilités */
           if an_ej=. then do;
              %if "%substr(&departs.,1,3)"="mat" %then %departs_matrice;

              %else %if "%substr(&departs.,1,3)"="log" %then departs_logit;

              %else %departs;
           end;
        %end;
     end;
```

Call of the "insurance period update" macro (the same as for working population 1)

Call of the "best wages calculation" macro (the same as for working population 1)

Table *older people* (retired generations, between 71 and 115)

Death calculation (the same as for working population 2)

Table *deceased*

Glossary

Conseil d’orientation des retraites (COR) : the *Conseil d’orientation des retraites*("Pensions Advisory Council") is a permanent body which brings together members of Parliament, representatives of the social partners, experts, and State representatives. Its main purposes are to monitor the French retirement system and to put forward recommendations for public policy concerning retirement, on the basis of expertise and consultation with all the partners involved.

Early retirement : in France, wage earners in private firms can retire from 60. However, since 2004, one can retire from 56 (55 for handicapped person) in the case of early careers, long insurance and contribution durations.

Echantillons inter-régimes de cotisants (EIC) : quadriannal sample of contributors from all schemes achieved by the Direction de la recherche, des études, de l'évaluation et des statistiques (DREES) from the French Health Ministery. This sample contains insurance periods data given by pension schemes (kind of period, wage or income, …). It allows a better understanding of combinations of insurance periods.

Echantillons inter-régimes de retraités (EIR) : quadriannal sample of pensioners from all schemes achieved by the Direction de la recherche, des études, de l'évaluation et des statistiques (DREES) from French Health Department. This sample contains old age pensions data. It gives knowledge on overall pensions (from various schemes).

Fall in the pension rate : fall applies to the full pension rate (50%) in case of insufficient duration and before 65 years old. The rate was 1.25% for each missing quarter for people born before 1944. It is planned to be progressively reduced, and set to a 0.6875% fall for people born in 1952 and after.

Institut national d'études démographiques (INED) : founded in 1945, the *Institut national d'études démographiques* (INED) has to "study demographic problems in all their aspects. To this end, the Institute will collect the relevant documentation, conduct surveys, carry out experiments and follow experiments conducted abroad".

Institut national de la statistique et des études économiques (INSEE) : founded in 1946, the *National institute of statistics and economic studies* (INSEE) collects, produces, analyzes, and disseminates information on the French economy and society. INSEE is responsible for the coordination of the France's official statistical service. It represents France in European Union institutions and international bodies in charge of statistical harmonization.

Notional defined contribution (NDC) system : pay-as-you-go scheme where contributions are fictively accounted, revaluated and converted to pension, on the basis of life expectancy.

Pension rate : the pension rate is determined by the number of quarters credited to the recipient’s account and the number of quarters required to be eligible to "full pension", which depends on the recipent’s generation and on his/her age at the actual retirement date. The full rate is the maximum rate of 50%. A recipient is entitled to full rate if he/she has contributed for the required insured period, or if he/she is recognized as unfit to work or disabled, or if he/she is at least 65 at retirement.

Quarter of insurance duration : 3-months insurance duration, based on wage or some kinds of periods (sick leave, maternity leave, unemployment, conscription,…).

Reference wage : average annual wage revaluated following price index. From 10 best to 25 best revaluated wages (from older to younger generations).

Social security ceiling : in the *régime général*, national insurance contribution are constrained by social security ceiling : most of contributions are calculated from a wage limited to the ceiling. The social security ceiling depends on average individual wage and is raised each year in january.

"Surcote" or pension bonus : higher pension rate achieved in case of insured works after full rate eligibility (after 60 and after legal duration). The rate is between 0,75% and 1,25% for each supplementary quarter, depending on generation.

Unfit to work and disabled pension : pension reserved to unfit to work and disabled people, for 60 or more. Always calculated with a full pension rate, even if the contributor does not have the number of quarters required to be eligible to this full pension rate.

Widows pensions : pensions given to the surviving spouse of a contributor. In the régime général, widow's pension is means-tested and corresponds to 54% of the pension the deceased had or would have had.

Bibliography

Beaumel C., Vatan M. (2008), « La situation démographique en 2006 », Insee résultats n. 84, august 2008.

Bonnet C., El Mekkaoui de Freitas N. (2004), « Retraite et patrimoine financier des ménages », Etudes et résultats n°330, august 2004.

Caillot L., Chaput H., Colin C., El Mekkaoui de Freitas N., Michaudon H. (2003), « Echantillon interrégimes de cotisants (EIC). Tome 1 : Procédures statistiques de constitution de l'EIC » DREES, Série Statistique, working paper n° 50, march 2003.

Chambaz C., Hourriez J-M., Legendre N. (1999), " Le niveau de vie des retraités en 1995 ", Retraite et société n°28/1999.

CNAV (2007), Recueil statistique 2007.

Commission des Comptes de la Sécurité Sociale (CCSS) (2008), Rapports annuels sur la sécurité sociale de juin et septembre 2008, http://www.securite-sociale.fr/chiffres/ccss/ccss.htm.

Conseil d'Orientation des Retraites, documents de travail www.cor-retraites.fr.

Debrand T. et Privat A.-G. (2004), « Salaires individuels et évolutions macroéconomiques en France », Revue de l'OFCE, n° 89, april, pp. 271-301.

Insee (1999), « Le modèle de microsimulation dynamique DESTINIE », document de travail de la Direction des Études et Synthèses Économiques de l'INSEE, G 9913, august 1999.

Mincer J. (1974), « Scholling, Experience and Earnings », Columbia University Press, New York.

Mincer J., Polachek S. (1974), « Family Investments in Human Capital : Earnings of Women », Journal of Political Economy, vol 82, n° 2, pp. S76-S108.

Ministère de la Défense, bilan social, www.defense.gouv.fr

Poubelle V., Albert C., Beurnier P., Couhin J., Grave N. (2006), « Prisme, le modèle de la Cnav », Retraite et société, n°48, pp. 202-215

Robert-Bobée I. (2006), « Projections de population 2005-2050, pour la France métropolitaine », Insee Résultats n° 57, september 2006.

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