LoLitA

Dynamic models for human Longevity with Lifestyle Adjustments

Projet ANR Blanc 2013, SIMI 1

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Contents

1 Résumé de la proposition de projet / Executive summary

The present project aims to develop models for the uncertain long term development of human longevity and methods for managing longevity-related risk in pensions and long term health care. From a mathematical point of view, this requires advances in stochastic models for population dynamics and in certain classes of semi-Markov models, development of advanced numerical methods for such models, and development of new statistical methods (online change-point detection, calibration issues in longevity and long term care models,...). The project is composed of six interconnected tasks, concerning respectively population dynamics modeling, long term care contracts, advanced simulation methods, multi-year solvency issues and joint stress tests, statistical aspects of longevity risk, and finally management of longevity risk in pensions.

The first task is devoted to stochastic models for population dynamics, which go beyond the deterministic models used in demography. Inspired by recent advances in the field of ecology, especially Individual-Based Models, we are interested in constructing and studying particle systems including specific individual characteristics, suited to the analysis of short and long-term longevity risk.

In the second task, we introduce multi-state processes with path-dependent intensities (semi-Markov and beyond) for actuarial analysis of various forms of long term care insurance. Stochastic models for longevity and long-term care are computationally demanding.

The third task is devoted to advanced simulation methods for population dynamics models of high complexity. These models are applied to actuarial products (life insurance, variable annuities, etc) with excessively long maturities, hence also simulation time. We will devise, adapt or transfer advanced sophisticated techniques (extrapolation, variance reduction, semi-closed forms, quasi-Monte Carlo) to provide a flexible and powerful simulation toolbox (fast computation, rare events, local refinements, etc...).

In the fourth task, we consider average and long-term solvency issues, and develop extreme scenario generators and joint stress tests for longevity and long term care. We also study aspects of behavioral risk associated with pension and long term care insurance.

In the fifth task, we address various statistical issues that arise in the context of longevity. Our goal is to introduce new statistical procedures for various types of models for mortality, longevity, and population dynamics. These methods will partly rely on extreme value theory, change point detection techniques, estimation procedures for stochastic differential equations, and bootstrap methods.

In the last task, we revisit the traditional paradigm of life insurance, whereby non-diversifiable economic and demographic risk was shared by the insured. A solution with index-linked payments is proposed. A unified approach is taken to the with-profit scheme, encompassing all forms of bonuses, and pursuing ideas of experience-based first-order technical basis and optimal bonus schemes. An extension to inter-generational risk sharing is proposed and examined.

To sum up, we consider **in some integrated way** important sources of longevity and long-term care risks, their representation with innovative models, their estimation, the way they can be analyzed by new mathematical techniques and computed through advanced simulations and other numerical methods. The mathematical models are aimed at generality and unification, and their applications are aimed to be timely, addressing current risk management issues in longevity, long-term care, and pensions.

2 Contexte, positionnement et objectifs de la proposition / Context, position and objectives of the proposal

2.1 Contexte et enjeux économiques et sociétaux / Context, social and economic issues

Most developed countries are currently experiencing unprecedented improvements in longevity. These developments raise a number of problems to which historical experience offers no answers. Improved longevity puts pressure on existing insurance systems such as health insurance and pensions, on public health services, and on social security. For instance, occupational pension schemes need to find adequate funding with fewer workers and more retirees in the future, and financing of state pensions and benefits must be adapted to the ageing of the population and the ensuing transform of needs. Ageing may also modify individual behavior, for example concerning risk aversion, investment, and savings. Certain intergenerational issues also arise from fluctuations in the age composition of memberships in pension schemes and in national populations, key words being solidarity, social cohesion, and - of course - economic sustainability. This way, a number of developed countries are poised to increase the retirement age by 2 to 5 years in order to account for the aging of the population in the funding of state pensions. Also insurance companies and pension funds systems are also facing a number of challenges related to longevity risk, notably of significant longevity improvements in the future. More capital has to be raised to offset long-term risk, a case in point being new European regulation of banks and insurance companies in the wake of the financial crisis. The ongoing move from defined benefits to defined contributions in occupational pension schemes means that longevity risk, formerly carried by the sponsors, is increasingly passed on to the policyholders. In addition, insurance companies and pension funds are facing the heterogeneous evolution of policyholders mortality. There is a bias, known as basis risk, between the mortality in an individual portfolio and that of the national population – a result of selection effects. Prospective life tables containing longevity trend projections are frequently used, but are no longer sufficiently accurate to measure the the longevity risk of individual insurance companies or pension funds. Among the many standard stochastic models for mortality, some have been inspired by the credit risk and interest rate literature, and as such produce a limited definition of aggregate mortality by age and time. Moreover, because of the long-term nature of longevity risk, accurate mortality projections are delicate.

A real need for new points of view on mortality modeling emerges from this context. The necessity to define and test political reforms has to be helped with new theoretical and numerical tools, which can contribute to offer guidance for governmental strategies at social and political levels (e.g. immigration and retirement age policy). At the same time, it is necessary to identify and measure the risk exposure of specific insurance companies and institutions. New methods, studied in an interdisciplinary research group, could provide useful benefits for longevity risk analysis and constitute a real basis for a unified regulatory system.

Increasing longevity is shifting the age distribution of populations toward older age groups. One question, that has been raised for several years and is still raised, is whether people will be live in wellness during the gained years of life expectancy or whether they will require all along external assistance to manage their daily life. It seems realistic to assume that the reality will be somewhere in between, but everybody is convinced that the increasing life expectancy will cause an increase in the demand for long term care in the coming decades and that long term care expenditures will represent a significant financial risk for the elderly. European countries offer various examples of organization, financing, and delivery of long term care. The mix of public and private funding, i.e. the balance between public financing that spreads risk broadly across the entire population and private responsibility through individual cost-sharing and family care-giving support, differs greatly among these countries. Since 2002 France has experimented a universal program which covers people age 60 and older but vary benefits according to income. For those who do not qualify for sufficient public benefits private insurance offers an interesting opportunity. The French long term care insurance market is one of the two first leading markets with the American market that can claim over 25 years of experience. However, they differ in terms of proposed solutions to the issues of long term care products.

The long term care risk is today very complex in terms of assessment and evaluation. There is a great deal of uncertainty about the extent to which the loss of autonomy has changed over time and could change for future generations. Moreover the cost factor – the rate of inflation in care services – represents an intertemporal risk that affects everybody in a pool. The interdependence between risks makes diversification harder whilst the sequential correlation of costs may make diversification across cohorts impossible. Therefore it is not clear whether the long-term care aggregate risk can be reasonably predicted.

The European insurance industry will soon be expected to comply to the new Solvency II Directive. The regulatory standards of the directive place emphasis on the manner in which insurance company endorsed risk should be handled so that it can withstand adverse economic and demographic situations. The regulation is scheduled to come into effect by 2015, and will certainly enhance the development of risk transfer solutions for insurance-risk generally, as well as for longevity and long term care risks in particular. It also increases the need for advanced and reliable simulation methods for longevity, mortality, long term care and savings insurance portfolios.

2.2 Positionnement du projet / Position of the project

This ANR project proposal is not the continuation of any ANR or European project. It benefits from the experience of participants (El Karoui, Hillairet, Loisel, Salhi) to the Longevity risk project of the research chair *Dérivés du Futur* (2007-2012). Let us mention that several recent ANR projects included studies of population dynamics, such as ANR MANEGE (Modèles Aléatoire en Écologie, Génétique et Évolution) and ANR MAEV (Modèles Aléatoires de l'Évolution du Vivant). However, they mainly focused on evolution and genetics purposes in ecology, and were thus rather remote from our project. Similarly, some recent ANR projects addressed numerical methods and advanced simulation techniques: ANR CGPMF (Grid computing, resp. UPMC G. Pagès). This ANR project was more oriented toward distributed computing (grids) than GPGPU with applications to diffusion models. ANR BigMC was mostly applied to continuous dynamical systems (molecular dynamics).To the best of our knowledge, no ANR project aimed at modeling long term care. The most related projects are those launched by the ANR and CNSA (Caisse Nationale de Solidarité pour l'Autonomie) for the Ambient Assisted Living joint programm, which is a development funding programm for innovative Information and Communication Technologies based products, services, and systems.

Our project contains some advances in mathematics, in particular for population dynamics models in random medium (properties, statistical inference, interacting particle systems, changepoint analysis,...).

2.3 État de l'art / State of the art

We now present the state of the art in the main fields that are relevant for our project. In each field, some participants of this ANR project are either specialist or have obtained preliminary results.

Classical longevity models, basis risk and relational models.
In classical dynamic mortality models (see [64], [99] and [21]), death probabilities (or mortality intensities) are represented as functions of age, period (calendar year) and cohort (year of birth) parameters and time series. From a practical point of view, such models are generally applied to large data sets, and thus are most suited to model mortality rates for an underlying national population, but the final goal is to model mortality rates specific to subpopulations with particular characteristics (population of a small country or region, individuals with a specific disease, insurance portfolio or sectorial pension funds). To overcome this issue, relational models (see [30]) offer an alternative when the specific data is observed for a limited period. Some techniques aim at linking together both mortality rate levels and trends.These techniques are static, and any discrepancy between the two sets of mortality figures represents a significant risk for the evaluation of the future mortality of the subpopulation; this is referred to as basis risk. Recently, some dynamic frameworks have been explored to link two population mortality dynamics. In particular, co-integration is used to capture potential equilibrium between the two sets of mortality and thus offers a quite robust tool to jointly project the mortality rates, see e.g [100].

Changepoint analysis and ruptures in co-integration relations.
Change-point analysis aims to identify changes in parameters of a model soon after they occur. Most of existing results provide an asymptotic study of the estimators (see e.g. [26] or [5]). This asymptotic framework (which generally consists of assuming that the amplitude of the change is large enough compared to the time elapsed since the change) is not adapted to the necessity of understanding the behavior of these techniques in cases where they are decisive (just after the change, and/or for changes of small amplitude). Non-asymptotic results have been provided mostly in a Gaussian framework (see [63], [44]) without considering the stability of these approaches under deviations from the Gaussian assumption. [88] investigated bootstrap procedures in a non-Gaussian framework for survival data, and performed estimation and model selection.

In the longevity field, change-point detection schemes are of special importance. Since longevity is a systemic risk, especially due to the uncertainty surrounding the trend risk, quickest detection schemes allows sequential monitoring of any deviation of the actual trend from the pre-defined one. It is worth mentioning that such monitoring offers a valuable tool for the regulators and risk managers. The latter should assess dynamically the adequacy of capital requirements under parameter uncertainty. In the literature, [102] investigated the use of the so-called cumulative sums (CUSUM) introduced by [89] in life insurance practice and in particular the detection of abrupt changes on mortality trend. In [101], the authors show that an [72]-like procedure based on minimization of the time to event is optimal for detecting breakpoints in proportional hazard models in the vein of [80]. The latter is used to link two mortality rates which are likely to change over time and induces a change on the underlying relationship.

Population dynamics and particle systems.
In order to reduce the basis risk faced by insurance companies and pension systems, we are interested in the area of adaptive dynamics for structured populations, initially developed for ecology purposes. Recent models, known as Individual-Based Models, take the form of stochastic interacting particle systems representing the evolution of a population at the level of the individual. These models were first studied for populations structured by traits (see e.g. [38]), i.e. each individual has its own characteristics. Then they were extended to describe populations structured by traits and also age (see e.g. [106] and [37]), which can have a non-linear behavior through time, for example to model biological age. In the field of macroeconomics, most governmental bodies, like the French Institute INSEE (French National Institute of Statistics and Economic Studies), use models (*Destinie* for INSEE) based on representative samples of national populations in order to test economic scenarios and retirement reforms. Computation in such models rely on simulation of the evolution of each individual in the population, which is time-consuming and therefore doable only for limited projection horizons. Certain Individual-Based Models are based on inspections of one randomly selected individual. Random inspection times have a frequency adjusted to the size of the population. This makes Individual-Based Models numerically efficient and well adapted to analyzing and simulating the long-term behavior of large populations. In this context, further research has been made to adapt and extend probabilistic models studied in ecology (see [38] and [37]) to the demographic development of human populations. In the Phd Thesis of H. Bensusan (see [8]), supervised by N. El Karoui, this kind of models are applied to national population projections, evaluation of retirement and migration policies, and analysis of longevity risk in insurance. More recently, with the wish to gather economists, biologists and demographers, people involved in the proposal organized the international conference "Longevity risk models: an inter-disciplinary approach" in Paris (May 2011). This interdisciplinary scientific monitoring could be extended in the health field to general practitioners. The research program addresses the robustness of this model, in particular improve its statistical stability and numerical efficiency for population projection.

Epidemiology models.
Traditional models for human longevity do not account for the risks due to the propagation of infec-

tious diseases. These risks, however, can be significant. For instance, the epidemic of SARS (Severe Acute Respiratory Syndrome) in 2002-2003 had a large economic impact in Asia. In Europe, a rough estimation of the probability of a flu epidemic gives an approximated value of 2% per year. There is a vast mathematical literature on epidemic models. We will consider an important class of models which are concerned with infectious diseases of the S-I-R (Susceptible-Infected-Removed) type (see e.g. the review by [65]). So far, little work has been done on actuarial applications of such models (the main reference is a recent paper by [36]). Our purpose is to incorporate S-I-R epidemics in the theoretical models for longevity.

Semi-Markov models for long-term care insurance risk.
A number of papers use multi-state Markov models in studies of long term care insurance (see, e.g., [68], [47], [27], [48], [49]). However, such models assume that the instantaneous rates of transition from the current state to each of the possible destination states depend only on the current state, thus ignoring the duration in the current state. More sophisticated models are needed to accommodate the widely experienced fact that the mortality rate depends on state duration, especially in the state lost autonomy. A semi-Markov model turns out to be a more realistic long term care insurance model. It was first introduced by Hoem and Iosifescu Manu in the actuarial field (see [50], [52]) and then Waters to permanent health insurance (see [110], [111], [112], [113]). Recent books on semi-Markov processes with applications to insurance are [53] and [31]. In particular Denuit and Robert considered non-homogeneous semi-Markov models for the analysis of long term care products in [31].

Long term care and prioritization of health expenses.
Health economics is an area in the interface of medical science, health care studies, and economics. It aims to answer such questions as how to assess the efficiency of a given national health services budget, how to compare alternative budgets, how to allocate an increase of (or cut to) a given total budget. Methods are fetched form many different areas, notably cost-benefit analysis, economics of the firm, welfare economics, and operations research. The main outlet of research in the area is *Journal of Health Economics*. Three representative references are [34] and [104] taking a static view and using mathematical programming methods, and [24] analyzing client/consumer preferences based on utility analysis. Models and methods from actuarial science have not been invoked in any noticeable way.

Models for lifestyle adjustments involving obesity and food contamination.
Food safety is currently receiving increasing attention both in the public health community and in scientific literature. In addition to epidemics like SARS or avian flu, longevity of individuals may be affected by other types of epidemics such as obesity and food contamination. The study of dietary exposure to food contaminants has raised many stimulating questions and motivated the use and/or development of appropriate statistical methods for analyzing contamination data, see [15], [14] for instance. In [12], a dynamic stochastic model for dietary contamination exposure has been proposed, which is driven by two key components: the accumulation phenomenon through successive dietary intakes and the kinetics in man of the contaminant of interest that governs the elimination process. This has raised the problem of analyzing some particular ruin models which are quite close to the one studied in insurance and hydrology. While a detailed study of the structural properties of the exposure process, such as communication and stochastic stability, has been carried out in [12] and [13], several problems remain in theory as well as in practice: for instance, the influence of the overexposition of multiple contaminants on life expectancy and their interaction over time could be better understood by using multivariate models. Moreover, for some contaminants (e.g. methyl-mercury) the probability of crossing the safety level is relatively small, but the consequence on health is extremely severe: for such contaminants special attention should be paid to the problem of computing the probability of rare events using multilevel splitting (see [55], [42]) or importance sampling techniques (see [28],

and [13] for an application).

Advanced numerical methods related to a range of topics in the proposal.
As concerns numerical complexity involved in population dynamics models, more attention has been paid so far to the deterministic asymptotics of mean field models, typically McKendrick-Von Foerster's Partial Differential Equation. New simulation tools are needed, following the pioneering works [38, 106] and [8] in the longevity field. A main issue is to speed up the simulation of such interacting particle systems (see [29] for recycling Von Neumann's acceptance-rejection method) by avoiding degeneracy or freezing phenomenons (a classical problem met in their simulation) and by adapting the simulation procedure to recent high performance computation device (GPGPU, see [92]) which needs parallelization. We also need to enhance the analysis of rare events, which are important for applications by extending adaptive importance sampling methods (see [67]). More generally the simulation and statistics toolbox for such models must be enriched and developed (among many other aspects one may think of interpolation by kriging see $e.g.$ [25], Richardson-Romberg interpolation (introduced for diffusions in [105]), quasi-Monte Carlo method [93] to speed up simulations, etc...).

Simulation issues in life insurance.
The complex underlying options, the various asset-liability interactions and the granularity of the insured profiles (see e.g. [62] and [95]) make it difficult to simulate life insurance liabilities through years. These economic balance sheets forecasts can be made through Nested Simulations as developed by [45] and presented by [11] in an insurance framework. This integrated Monte-Carlo methodology considers scenarios whose nature is highly stochastic due to the multiplicity of underlying risks that must be jointly simulated, be it market risks or specific life risks such as longevity or mortality (see [97], [35]). In practice, the implementation of Nested Simulations turns out to be excessively time consuming and typically exceeds insurers´ operational constraints. In order to make the approach faster, several areas have been studied recently such as the development of closed formulas for simple cases (see [17]) or the use of computational proxies (see e.g. [6], [22], [108]). In the project, we hope to take advantage of the complementarity of the team to address these issues.

Policyholder behavior in life insurance.
Accurate predictions of lapses remain a challenge due to a variety of factors (personal needs, contract features, tax constraints, budget constraints) involved in purchase of insurance. As suggested in [79], structural as well as temporary factors should be considered in the decision making process through use of regression techniques. When the premium size is mainly determined by the policyholder's health, other matters such as adverse selection and moral hazard ([16]) have to be addressed. This is clearly a hard task, even if insurers partly control these effects thanks to well-known incentives (e.g. deductible, medical examination). Early works by [60] and [54] developed generalized linear models ([75]) in this context, while others ([2], [103], [107]) used financial methods to price the surrender option embedded in life insurance policies. All of them were faced with the same issue: overdispersion of the lapse decisions. This problem is partly solved by using finite mixtures ([78]). However, another attractive strategy that should be investigated are hidden Markov models. The main advantage would be that the policyholders' behaviour would be allowed to change over the contract period.

Risk sharing: within and across generations.
Already about a century ago life insurance mathematics had devised principles for perfect management of demographic and financial risk through so-called risk sharing in the form of *with-profit* schemes designed as follows: Upon the inception of the contract the premiums and the benefits are guaranteed in nominal amounts for the entire contract period; Premiums are determined by the principle of equivalence (expected balance between discounted premiums and discounted benefits) based on a worst-case economic-demographic scenario called the *first order (technical) basis*; The systematic surpluses generated by the conservative premiums are redistributed to the insured in ar-

rears as bonus in such a manner that the principle of equivalence is attained conditionally, given the course of economic-demographic events over the contract period. The approach was presented in a framework modern stochastic processes theory in [83], and various bonus schemes were analyzed in [84]. Optimal stochastic control methods were applied to the problem of bonus reallocation in [82] (based on a PhD thesis supervised by R. Norberg). The idea of index-linking the contractual payments in such a manner as to eliminate solvency risk was presented in a rudimentary form in [86]. Intergenerational solidarity is one of the pillars in state pension systems and is one of many different forms of income transfer through taxation and public spending. Apparently triggered by the improving longevity prospects, the issue is currently on the agenda of the EU and many of its individual member states. A recent paper from Netspar [18] discusses intergenerational solidarity within occupational pension schemes funded by contributions, whereby transfers across cohorts is a matter of negotiation. Apart from this reference, the literature offers little in terms of theoretical approaches to transfer of longevity risk across generations.

2.4 Objectifs et caractère ambitieux/novateur du projet / Objectives, originality and novelty of the project

The present project aims to propose models dedicated to the long term and uncertain development of human longevity, and also methods for managing longevity-related risk in pensions and long term health care. From a mathematical point of view, this requires advances in stochastic models, numerical methods and statistical aspects.

Concerning the probabilistic study of the microscopic population dynamics model described in Task 1, the main mathematical obstacle is to understand the role and the influence of the random macro-environment. In this model, the demographic evolution of the population is stochastic, and this evolution is done in a random medium. In this context, two sources of randomness influence the behavior of the population. To the best of our knowledge, no previous work has been made in this direction in the field of ecology. A theory of this kind of model has to be built in order to address all probabilistic issues. The first analysis of the model described in Task 1 will be increased by further research. Another obstacle faced is to identify the mathematical link between this method and other particle systems methodologies.

To the best of our knowledge, no numerical study has been performed for the dynamic population models described in Task 1. A technical obstacle is the necessity to provide long-term longevity scenarios, for large populations. This need suggests that numerical resources have to be used sparingly, and procedures have to be developed to optimize computational cost.

As statistical aspects are concerned, a main obstacle is the development of statistical procedures for probabilistic models of high complexity, including various parameters. Another obstacle is to ensure the robustness of the calibration method to calculate reliable numerical approximation of various quantities of interest.

Our project is also concerned with data issues. In order to reduce basis risk, we choose to take into account detailed individual characteristics. We thus want to obtain long term accurate projections of quantities of interest for longevity purposes. Using the specific subsample of the French population of INSEE, called *Echantillon Démographique Permanent*, we are facing the problem of the estimation of quantities of interest (in particular, demographic intensities) with a decreasing sample size with regards to the accuracy of the individual information. To overcome this issue, we will have to balance two effects: the uncertainty coming up with the detailed information, compared to the accuracy obtained thanks to individual specificities.

3 Programme scientifique et technique, organisation du projet / Scientific and technical programme, Project organisation

3.1 Programme scientifique et structuration du projet / Scientific programme, project structure

Here is a list of tasks covered by the project:

- **Task 0:** Coordination of the project and dissemination of results.
- **Task 1:** Population dynamics models for longevity risk.
- **Task 2:** Long term care contracts. Models, calibration, risk management.
- **Task 3:** Advanced simulation methods for longevity, long term care and savings models.
- **Task 4:** Multi-year solvency for longevity, long term care and savings insurance contracts. Joint stress tests.
- **Task 5:** Statistical aspects of longevity risk: fitting longevity models, basis risk analysis, change-point analysis.
- **Task 6:** Risk sharing in pensions and life insurance: within and across generations.

Task 0 is of course connected to the 6 other main tasks. We omit it in the diagram (Figure 1). All sub-tasks are interconnected. In order to be more precise, we highlight the sub-tasks of different tasks which present the highest level of connection from our point of view.

3.2 Management du projet / Project management

The project is composed of six tasks, addressed by groups working interactively and simultaneously. Each task is coordinated by a task coordinator. The project coordinator will regularly be in touch with task coordinators to manage the project efficiently. We will organize two full meetings per year at the project level. There will be more frequent meetings inside working groups and groups working on papers. We also identified an additional task (Task 0) dedicated to coordination and dissemination of results.

3.3 Description des travaux par tâche / Description by task

Task 0: Coordination of the project and dissemination of results
Coordinator: Stéphane Loisel. Main other participants: Coordinators of Tasks 1-6.

The 6 tasks are of course interrelated. The coordinator will organize two full meetings per year at the project level, and make sure that everyone is aware of the progress of each group. Each task coordinator will do the same at the level of the individual task. The coordinator and the task coordinators will regularly be in touch (meetings or conference calls) to monitor the progress of the project. More specifically, the coordinator of Task 3 (Gilles Pagès) will be in contact with the other coordinators to manage access to computation times of the computing hardware bought for the project. The coordinators will also work together to disseminate results of the project and to produce reports about deliverables and milestones, in connection with the *Pôle de compétitivité*. The project coordinator and task coordinators are personally involved in several tasks, which facilitates coordination.

Task 1: Population dynamics models for longevity risk
Coordinator: Nicole El Karoui. Main other participants: Bérard, Boumezoued, Hillairet, Loisel, Norberg.

Probabilistic study of longevity population models. We propose a new probabilistic Individual-Based Model for longevity purposes. This model allows to take into account individual characteristics, also called traits, such as socio-professional categories, education and marital status, which have a real

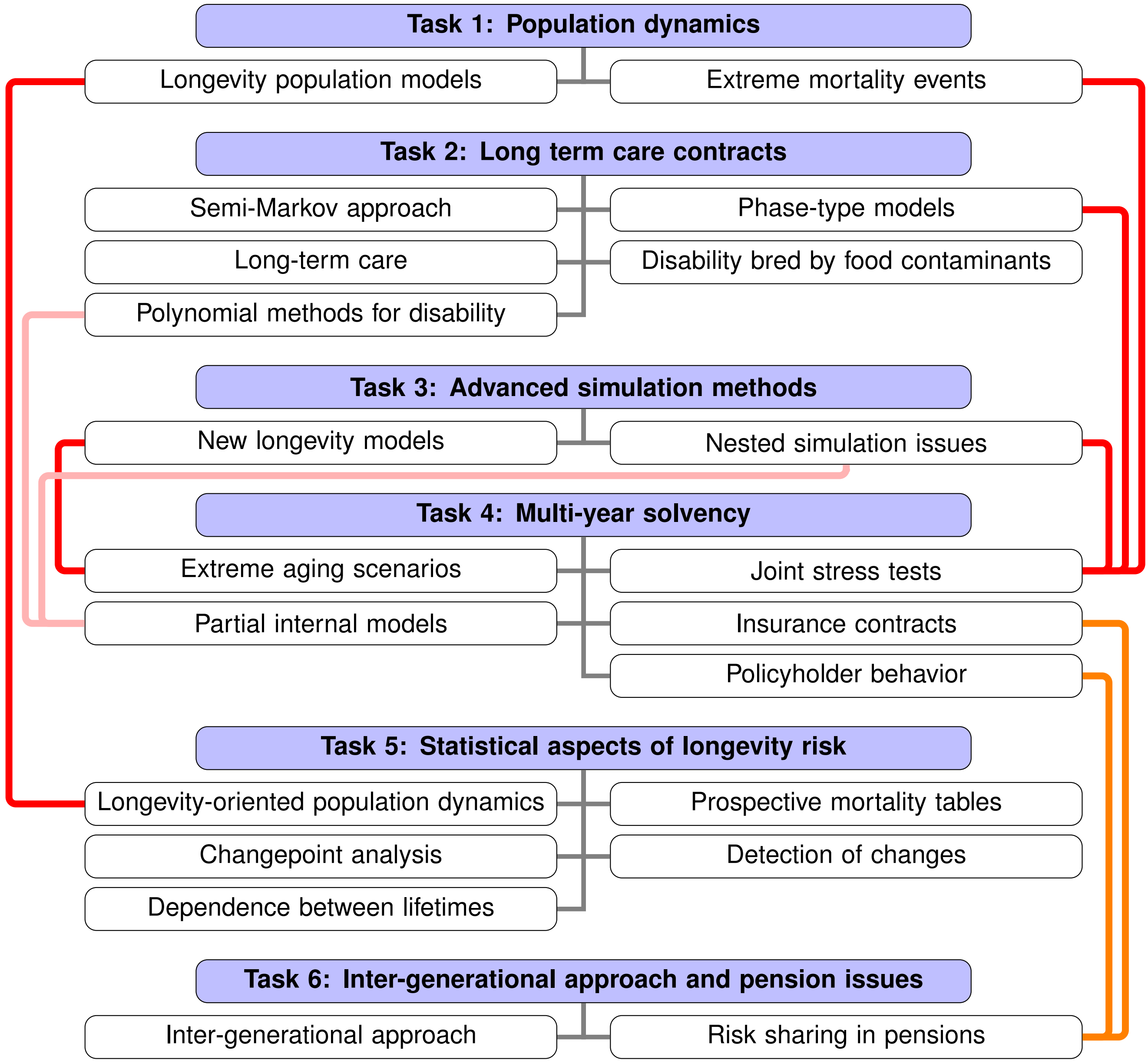

Figure 1: Tasks diagram

impact on demographic behavior. The population is subject to multiple changes at the level of individuals: birth or migration, death and evolution of their traits. For an individual, the probability of occurrence of these events, or their intensities, can vary with age and traits. The uncertainty on the evolution of the macroeconomic and environmental context is modeled by stochastic exogenous factors representing long term trends, short term fluctuations, and sudden shifts (e.g. catastrophic events).

Through this model, we want to derive properties in order to recover various quantities of interest on the evolution of the population, such as population composition in terms of characteristics and age, and useful risk measures on the population trajectories (extreme scenarios). We want also to better understand the aging mechanism. The model may be used as an experimental tool to test by simulation some new retirement, migration and environmental policies. Modeling the population structured by age and traits by a measure-valued stochastic process is done through a Stochastic Differential Equation (SDE) driven by a point process, depending on demographic intensities (birth, migration, death and evolution) of each individual. In a population framework, limit theorems lead to the convergence of this equation to a Partial Differential Equation (PDE), describing the deterministic population density. These two formulations (SDE and PDE) enable analysis of the impact of demographic parameters such as evolution intensities, environmental factors or aging speed, in order to determine the impact of individual parameters on the evolution of the population. Through this study, we want also to test the relative importance of some parameters in view of simplifying some evolutionary mechanisms. This model is flexible enough to include e.g. biological age, contagion, and competition for space and resources following changes in the environment.

Embedding extreme mortality events in longevity-oriented population dynamics models.
The first step of our research aims to develop a compartmental model to describe the spread of an epidemic. The population is divided into several groups of individuals: the susceptible, the infected, infectious, vaccinated cases and the removed individuals. Non-linearity and non-homogeneity in the transition rates represent the impact of the contagion and the age factor. The second step consists in introducing an actuarial context by incorporating the costs and benefits of medical care and vaccination. Various insurance strategies will be discussed. Results of stochastic combustion theory (see e.g. [9], [10]) will also be generalized to a spatial framework corresponding to the human population.

Task 2: Long term care contracts. Models, calibration, risk management.
Coordinator: Christian Robert. Main other participants: Bertail, Blanchet-Scalliet, Doukhan, Loisel, Pommeret and Tressou (food contaminants and long term care), Govorun, Planchet, Norberg, Rey-Fournier. External collaboration with doctors from Longevity institute (Paris 6), from ICM (Alzheimer) and from food contaminant specialists. External collaboration with the group led by M. Sherris in Sydney, and with P. Thérond (Lyon 1). Participation of Quentin Guibert as PhD student of F. Planchet.

Semi-Markov approach of long-term care insurance contracts.
Effective actuarial analysis of long term care products requires an understanding of the migration of insured individuals between states of loss of autonomy that affect the amounts of annuities. Multi-state processes, i.e. processes in which an insured is in one of a finite number of discrete states at any point in time, offer a natural tool to describe the history of the insured. In view of the rising popularity of stochastic mortality rate modeling, we want to propose and study new non-homogeneous semi-Markovian models, discuss their features and give new actuarial applications. Moreover, there is evidence that the transition intensities can vary significantly over the contract period, exposing the insurer to a systematic biometric risk. In order to deal with that risk, an actuary needs to forecast future demographical developments. This can be done in the form of point estimates, confidence estimates, or even stochastic processes for the transition intensities. Since very few studies investigated time trends in transition rates for multi-state long term care models, there is a need for statistical research in this area.

Phase-type models and health expenses.
Our first objective is to use phase-type methods to examine the distribution of future discounted health expenses over a random time horizon (e.g. the remaining life length), for the description of which we use the phase-type aging model introduced in [69]. The authors define a finite-state continuous-time Markov process to model the hypothetical aging process of an individual, where the states represent different states of health. It is assumed that annual individual health expenses increase with the health state and does so in a random manner. To assess the effect of this assumption we also plan to consider cases where the health expenses are constant for a given health state and when they are independent and identically distributed random variables. We intend to obtain the distribution in a recursive way by extending the algorithm suggested by [33], which is an extension of the widely used Panjer algorithm [94].

Our second objective is to use the phase-type aging model for a cost-effectiveness and cost-utility analysis, which are relevant in health and disability insurance. First, we need to extend the phase-type aging model to describe the evolution of a particular disease. Second, we need to assign cost and utility values to each health state of the extended aging model. An important indicator that we need to compute with the phase-type approach to perform such type of analysis is QUALY (quality-adjusted life years). The outcome of the analysis will allow us to estimate the impact of new and often expensive medicaments on the total health expenses, thus guiding decision makers in their choice of optimal treatment strategies.

Long term care and health expenses.
Optimal allocation of health budgets: Our theoretical starting point is the traditional actuarial description of the life history of an individual as a stochastic process on a finite space of different states of health. The intensities of transition between states are assumed to be known functions of the health budget. For an individual who is in a given state at a given age, the (remaining) *quality adjusted average life years (QUALY)* is defined as the weighted expected remaining life length, the weights depending on state and age. The efficiency of a given health budget can then be measured by the sum of all the QUALY-s in the population (or a proxy obtained by grouping the population into a relatively small number of age groups). The individual QUALY is readily computed by solving numerically a small system of differential equations (just ODE-s under Markov assumptions). The *sensitivities* of an individual QUALY with respect to the health budget are defined as the derivatives of the QUALY with respect to the entries in the health budget. These are obtained by solving the differential equations obtained by differentiating the primary differential equations with respect to the individual budget entries, the underlying theory being fetched from references [56] and [85]. The sensitivities of the total QUALY in the population is obtained through aggregation. Within the framework described we will consider variations of the budget constraint and the objective function. It is conceivable that the health expenditures can depend on the transition probabilities, which themselves depend on the health expenditures, a case in point being long term care where the expenses depend on the prospective number of survivors in different states of health. This would mean that the budget constraint becomes non-linear. It is also possible to work into the objective function (QUALY) more refined expressions of client/consumer preferences based on utility analysis as in reference [24]. The dynamic approach proposed here is new, its main merits being that causes and effects involved in health care spending are made explicit and bring to the surface the total impact of budget allocations through the intensities that govern all entities in the model for the population.

Disability bred by food contaminants.
The accumulation phenomenon of the food contaminant in the body occurs according to the successive dietary intakes, which may be mathematically described by a marked point process in a classical ruin model fashion. Assume that the chemical is present in a collection of P types of food. A meal is then modeled as a random vector whose p-th component indicates the quantity of food of type p consumed during the meal, with $1 \leq p \leq P$. Suppose also that the food of type p consumed during the meal is contaminated in random ratio regarding to the chemical of interest. Given the metabolic rate of the organism, physiological elimination/excretion of the chemical in between intakes is classically described by a differential equation (see [41] for an account on pharmacokinetics models). Supported by empirical evidence, one may reasonably assume the elimination rate to be proportional to the total body burden of the chemical in many situations, including the case of methylmercury. The metabolism with respect to the chemical elimination may itself be random. To evaluate the probability of ruin (that is the probability of crossing a safety level) impacting on the health of the individuals, Bertail *et al.* ([12]) made strong assumptions about the observed random variables. In particular, inter contamination-times, consumptions, contamination ratios, and elimination are supposed to be independent. Such assumptions may be realistic for very particular contaminants present in some special products (e.g. methylmercury) but not in contaminants present in a large number of products (e.g. dioxine or heavy metals). We would like to extend such models by introducing various forms of dependence: this may be done in several ways, either by introducing some copula structure between

the components or by considering some mixture models implying some hyperparameters. Finally it is also of interest to study multidimensional version of this model to understand correlation between contaminants. These models have been used mainly for contaminants but may also be interesting in studies of obesity (link to the consumption of fat and sugar) which has impact on aging and long term care.

Polynomial methods for disability.
Another complementary direction to study the probability of disability after contamination is to use an expansion of the associated density with respect to a basis of orthogonal functions. For instance, polynomial expansions can lead to exact expression of both the density and the probability distribution function. This method permits truncated series and it can be implemented to obtain numerical approximations of cost probabilities. As in the work of [43], the choice of the reference measure and the number of components in the polynomial expansion play an important part. The statistical aspect of this work concerns the problem of testing the equality of a cost distribution to a given reference distribution (or two cost distributions). The use of orthogonal polynomials suggests the construction of a smooth goodness of fit test (see the recent papers [40], [32]) with a data driven procedure based based on Akaike or Schwartz criterion (see for instance the discussion in [51]).

Task 3: Advanced simulation methods for longevity, long term care and pensions/savings.
Coordinator: Gilles Pagès. Main other participants: Bérard, Bienvenüe, Boumezoued, Lemaire, Loisel, Rullière, Védani. External collaboration with Laurent Devineau and specialists in particle simulation.

Simulation issues for new longevity models.
Microscopic models of population dynamics introduced in [38], [106] for ecology purpose have been recently revisited, especially in [8], to develop new models for longevity of human populations as well as the resulting financial and actuarial risks. This is basically a high dimensional point process (or equivalently a measure-valued interacting particle system) with random intensity depending on exogenous factors modeled by Brownian diffusions. This microscopic approach – and the resulting Monte Carlo simulation methods – is particularly flexible in terms of simulation (by contrast with the "mean field" PDE approach), although much more time consuming. The backbone of this sub-task is to devise or adapt new simulation techniques techniques to dramatically speed up the speed of the simulation of such models for large populations:
– Basic simulation methods of such process rely on an Acceptance-Rejection (AR) principle known as *thinning method* consisting in “carving" the random intensity from that of a Poisson process, which is easy to simulate. AR methods often have a bad yield, which can in turn be improved via various recycling methods (e.g. [39], [29]). Adapting these concepts to the population dynamics model described in Task 1 is a first (theoretical and numerical) challenge.
– Many quantities of interest in longevity are related to rare events. Their computation by simulation is greatly accelerated by importance sampling techniques when implemented through robust data driven procedures, such as those studied in [67] for diffusion processes. Transferring these techniques to this new model is a second challenge.
– Theoretical (and empirical) analysis of the time discretization error, keeping in mind Richardson-Romberg’s extrapolation (i.e. an appropriate linear combinations of estimators with different time discretization steps, see [90]). Cancelling the first order terms in the time discretization bias is a major issue in attempts to reduce the global “budget" of simulations for a prescribed accuracy-confidence.
– Quasi-Monte Carlo methods (Sobol’ sequences, etc) are known to speed up the rate of convergence of the Monte Carlo simulations ([93]), but they have less theoretical support when it comes to jump models. Further investigation is needed to elucidate how to use them for interacting particle dynamics like ours.
– In terms of risk assessment, it is important to know how to calculate by simulation large families of

risk measures, especially consistent and asymmetric risk measures like CVaR, etc. The *stochastic approximation approach* à la Robbins-Monro (see [4]), by its simplicity of implementation as a Monte Carlo like companion procedure, appears very promising.
– Finally, most models of longevity have, for intuitive reasons, a steady regime and it is a major issue to compute by simulation functionals *under this stationary distribution*. A whole machinery has been developed by several authors during the last ten years based on the time occupation measure of the Euler schemes with decreasing steps of jump Markov processes (see $e.g.$ [61], [91]) which can be adapted to this kind of dynamics. This last – more prospective field of investigation – is probably a major issue for applications.

Nested simulation issues in life insurance.
Closed-form solutions for the assessment and forecasting of life insurance liabilities are not frequent. In practice, extreme quantile values of Net Asset Value (NAV) at date $T > 0$ are usually empirically assessed through a Nested Simulations framework. This two-steps approach consists in simulating primary economic scenarios through the forecasting horizon (from $t = 0$ to $t = T$) followed by secondary risk-neutral economic scenarios, conditionally to each primary simulation. This enables one to compute Monte-Carlo estimators and provide an empirical distribution of NAV at date T. The greater the number of primary / secondary simulations, the more efficient the estimators for extreme quantile values (0.5% quantile at $T = 1$ year in the case of the Solvency II Capital Requirement assessment). However, the implementation of such a process is strongly time-consuming and operationally inefficient. In order to accelerate this process, one should consider the various techniques enabling one to locate the primary scenarios associated to the targeted quantile values. These techniques can involve statistical methodologies such as meta-heuristic approaches, or approaches linked with the economic utility theory such as working on certain equivalents of the conditional NAV. The latter field of investigation has yielded satisfactory operational results. One can observe in practice high levels of Kendall correlation between the NAV and its equivalent deterministic amount empirical distributions, especially for the most extreme outcomes. These results can be explained theoretically through the analysis of order statistics´ differences in the case of leptokurtic underlying distributions. We also want to implement kriging techniques to adress those issues.

Task 4: Multi-year solvency for longevity, long term care and savings insurance contracts. Joint stress tests. Policyholder behavior.
Coordinator: Stéphane Loisel. Main other participants: Boumezoued, Govorun, Milhaud, Planchet, Robert, Rosenbaum.

Extreme longevity risk scenarios.
In studies of rare events importance sampling can reduce simulation times greatly, the principle being to shift probability mass from likely to unlikely events (essential a change of measure). Thus, as mentioned in the description of Tasks 1 and 3, the flexible population dynamics model is well adapted to the use of importance sampling techniques which could be a tool for the analysis of variables of interest and particularly their distribution tails. These features could lead insurance companies and pension funds to identify adverse longevity scenarios and use this model for solvency purposes using techniques developed in Task 3. Some other extreme value aspects will be covered and involve integer-valued random fields and clustering of extremes.

Joint stress tests with both longevity and long-term care risks.
By using the phase-type aging model introduced in [69] as a mortality model we can study the effect of various complex events. The phase-type aging model uses a Markov chain to describe human mortality, the states of which represent different health states of an individual. The generator of this Markov chain contains mortality and aging rates for each state. One example of the stress test that we are going to consider is the decrease of the mortality rates for subsets of health states. This will

allow us to examine the financial impact of living longer in the states for which the treatment expenses are the most expensive. Applying time dependent coefficients to future cash flows, related to the survival of an individual, permits us to take into account external economics factors at the same time.

Construction of partial internal models with longevity and financial risks.
The Solvency II valuation framework clearly distinguishes poolable and non-poolable risks. Longevity risk, and more generally the risk of error on the model assumptions, belongs to the second category. Building an internal model for life insurance requires mixing the two kinds of risk in a particular way, as indicated in [46]. To build an efficient and robust model, one should seek to minimize the number of simulations, which are expensive and slow. Our main objective will be to build parametric and tractable models well suited to combine poolable and non-poolable risks in such an internal model. A possible way is to use the same ideas as in [17] but in a more sophisticated mathematical framework.

Insurance contracts embedding savings, longevity and long-term care.
Recent years have seen the introduction of a number of new insurance products that take longevity risk into account. These products, called variable annuities, appear particularly attractive to clients as they come with guarantees against certain downside risks and at the same time allows participation in upside moves of the markets. Therefore, they are a fast growing business in the life insurance industry, especially in the United States. From the insurer's point of view, pricing and hedging such products is a very intricate issue. Indeed, their maturity can be very long (for example the death of the client), their design is often complex, and mostly there is a lot of uncertainty as to policyholder behavior, especially the lapse rate (withdrawals from the contract before maturity). The common approach to pricing of these guarantees is based on historical lapse rates (see [7, 77]) and uses classical mathematical finance methods derived from the Black-Scholes framework. These practices are questionable. Indeed, the deterministic lapse assumption leads to an underestimation of the risk associated to these products, depending notably on the rationality of the clients. To take into account this risk, a more conservative and probably more reasonable approach is to use optimal stopping techniques, see [109, 81]. However, in all these methods, over so long maturities, the robustness of the Markovian models which are used, the stability of the parameters, and the relevance of the calibration procedures are arguable. Also, it is not clear that the model assumptions are always satisfied. Therefore, our first goal is to analyze the relevance of the usual methods, confronting them with mis-specification of models and parameters and with inadequacies of the assumptions. Then, since existing payoffs of variable annuities are probably often too complex, we want to propose a suitable design of such products. Our aim is to construct payoffs that can be reliably priced and hedged on the basis of longevity projections.

As mentioned above, some variable annuity products also offer some guaranteed withdrawal benefit to the policyholder, which enables the policyholder to withdraw more or less money in the savings account than expected in the default withdrawal plan of the retirement phase. Consequently, one must not forget to study policyholder behavior risk in order to have a clear picture of the sustainability of the pension scheme.

Policyholder behavior in savings, and potential changes due to longevity improvements.
Life insurance policyholders often have the opportunity to rebalance their initial investment (general account VS unit-link contracts). This trade-off causes huge transfers of money between asset managers (from pension funds, government, insurance companies, protection entities) and financial markets. From a behavioural viewpoint, the key point following the human longevity improvement lies in the mechanical increase of possibilities to undergo such decisions, together with their associated "lifetime" ([74]). This will clearly affect the management of life guarantees (mainly death, long-term care and critical illness benefits). Non-linear correlation risks are also likely to go up significantly, because increasingly policyholders will be guided by advisors ([70]). This might create large scale copycat behaviour, whose qualitative (correlation structure) and quantitative (high-dimensional esti-

mation of common shocks models, [76]) assessment will be the core of the project.

Task 5: Statistical aspects of longevity risk: fitting longevity models, basis risk analysis, changepoint analysis.
Coordinator: Paul Doukhan and Matthieu Rosenbaum. Main other participants: Bertail, Boumezoued, Loisel, Lopez, Planchet, Pommeret, Salhi.

Estimation in longevity-oriented population dynamics models.
A fundamental step concerns the calibration of the population dynamics model described in Task 1 in an incomplete data framework, which is usual when dealing with mortality data including detailed individual information. Although it is possible to use the Human Mortality Database (www.mortality.org), allowing e.g. comparison of mortality in several developed countries, our goal is to calibrate the model on specific data from INSEE. This dataset, known as *Échantillon Démographique Permanent*, includes detailed individual information for a representative subset of the French population[1]. In our case, we want to propose a robust calibration method taking into account individual characteristics, to study the propagation of the estimation error of the parameters through the SDE and the PDE, and then propose coherent uncertainty measures for quantities of interest. This could lead to useful comparisons with regard to classical actuarial tools used to study longevity risk (see e.g. [20] and [64]).

Construction of prospective life tables for insurers.
In the context of prospective mortality tables for insurance portfolios, the most commonly used models (see [20]) may be inappropriate due to the shallow depth of the historical record. We must then turn to other approaches using positioning techniques (see [96] and [59]) or semi-parametric techniques (see [98]). This leads to the need of considering a number of risks inherent in this context, including the estimation risk (see [59]), the impact of heterogeneity (see [57]) and uncertainty associated with the determination of the trend (see [58]). This risk can be considered as a particular case of model risk.

Changepoint analysis in longevity trends in general.
Prospective models used for forecasting the evolution of mortality all rely on a stability assumption: the trends observed in the past are assumed to be relevant to prediction of the future. However, this assumption may not be valid over a long period of time. Change-point analysis techniques aim to detect deviations of the model as soon as possible, in order to adapt the statistical approaches used to forecast mortality. The aim of this work is to produce detection tools that are able to identify abrupt changes soon after their occurrence, but also progressive changes that require new calibration of the models.

Basis risk, co-integration and detection of changes in longevity co-integration relations between several populations.
We would like to explore a test for assessing the stability of a temporal linear model inspired by some previous work by [3]. The test is based on the consistency of the least square estimator estimator whose behavior is studied on (almost) all subintervals over time. In the framework of cointegration it is expected that such test has a non-standard limiting distribution. The test proposed in [3] allows to detect breakpoints on the boundaries under reasonable assumptions. Consider a simple regression model $y_t = x_t\beta + \varepsilon_t$, with $E(\varepsilon_t|x_t) = 0, V(\varepsilon_t|x_t) = \sigma^2, t = 1, ...T$ with the variable x_t and y_t eventually integrated of order 1. A common approach to detection of ruptures in this kind of model is to use the likelihood ratio between observations in $[0, t]$ and $[t + 1, T]$ for varying t , and to detect the time t_0 at which this likelihood is maximum, (see for instance [19], [1]). The drawback of such tests is that they are are not robust to several structural changes and are unable to to detect changes in the

[1] We thank INSEE for this precious data set.

boundaries of the observation period. Another solution is to consider the collection of estimators of β say $\widehat{\beta}_n(u,v)$ over period $[[Tu],[Tv]]$, for $0 \leq u < v \leq 1$. In the absence of structural change, this estimator converges to the true value β under some standard assumptions. Barbe and Bertail [3] have studied the $\Delta_n(u,v) = \widehat{\beta}_n(u,v) - \widehat{\beta}_n$ seen as a process indexed by u and v in a non-dynamic framework and have proposed a test of heterogeneity (or structural change) in the regression based on the behaviour of $\sup_{u\in[0,1], v\in[0,1]} |\Delta_n(u,v)|$, $\int_0^1 |\Delta_n(u,v)|^p dudv$. Our purpose is to study the ability of such a procedure to detect the changes in longevity in cointegration relations and evaluate the power of such tests against local alternatives. The main interest of such tests is that they should enable detection of changes even on the boundary of the interval of observations so that online detection of structural change for incoming data may be feasible. This may be of interest, not only in insurance, changes but also in finance for some portfolio selection models based on cointegration.

Evolution of dependence between lifetimes of individuals

Many insurance contracts (e.g. pension with a reversion clause) are linked to the lifetimes of several individuals. Various models have been proposed for dependence of lifetimes, the most frequent being survival copula models. In this work, we aim to model the evolution over time through a random dependence parameter, to reflect the fact that sociological changes in the structure of the couples may impact this dependence. Goodness-of-fit procedures, such as the one presented in [71], may be extended to this framework. A related approach is to consider a dependence model of Schur-constant type (see e.g. [23]). In particular, a property of monotonicity of finite order (see [66]) will allow us to point out and exploit a link with the copula models.

Moreover, this dependence between the lifetimes may be subject to some evolution. Indeed, in the example of the lifetimes of two members of the same couple, the evolution of the lifestyle should have an impact of this dependence. In [73] it is shown that, for some particular data, this dependence decreases for the youngest generations. In this project, we will focus on dependence model that allows us to introduce some time evolution factor, and on estimating the parameters of such models. Goodness-of-fit procedures will also be developed in order to chose between the different model that may be proposed.

Task 6: Risk sharing in pensions and life insurance: within and across generations.
Coordinator: Ragnar Norberg. Main other participants: Barsotti, El Karoui, Eyraud-Loisel, Hillairet, Loisel, Marceau, Salhi. External collaborations with Enrico Biffis (Imperial College, London), Daniel Bauer (Georgia State University, Atlanta)

Risk sharing in pensions funds and insurance companies.

The purpose of the present project is to pursue the idea of risk sharing in life insurance and develop it further in three specific directions: (1) Revisit the with-profit concept and reshape it in terms of the cash flow dynamics in a manner that, firstly, comprises the various forms of bonuses (cash dividends, terminal bonus, and guaranteed added benefits) and, secondly, allows the first order reserve to be based on technical elements that are dynamically adapted to experience ("prudent predictions"). (2) Work out in full generality what can be called perfectly index-linked insurance, whereby payments (premiums as well as benefits) are linked to financial and demographic indices in a manner that automatically ensures solvency and conditional equivalence. (3) Search out possible applications of stochastic control theory for jump processes (see [87]) in the context of risk sharing, in particular optimal redistribution of bonuses in with-profit and optimal design of payments in more general risk sharing schemes.

Intergenerational risk sharing.

The issue of intergenerational solidarity in pensions will be addressed in the spirit of actuarial principles for risk sharing. Our approach is to describe the dynamics of the total fund of the scheme, to stipulate a target ratio of inflation adjusted benefits to inflation adjusted contributions, and to control dynamically the contributions and the benefits at any time in such manner as to attain, to the extent possible, the target for each generation. Statistical projections of future mortality, studied in Tasks 1 and 5, will be an ingredient in this optimization problem.

3.4 Calendrier des tâches, livrables et jalons / Tasks schedule, deliverables and milestones

Tasks	Partners Involved		Year 1		Year 2		Year 3		Year 4	
	1	2	6	12	6	12	6	12	6	12
Task 0, resp. *S. Loisel*, coordination of the project and dissemination of results	X	X	X	X	X	X	X	X	X	X
Task 1, resp. *N. El Karoui*, population dynamics models for longevity risk	X	X	X	X	X	X	X	X	X	X
Task 2, resp. *C. Robert*, long term care contracts. Models, calibration, risk management	X	X	X	X	X	X	X	X	X	X
Task 3, resp. *G. Pagès*, advanced simulation methods for longevity, long term care and savings models	X	X	X	X	X	X	X	X	X	X
Task 4, resp. *S. Loisel*, multi-year solvency for longevity, long term care and savings insurance contracts. Joint stress tests. Policyholder behavior	X	X	X	X	X	X	X	X	X	X
Task 5, resp. *P. Doukhan* and *M. Rosenbaum*, statistical aspects of longevity risk: fitting longevity models, basis risk analysis, changepoint analysis	X	X	X	X	X	X	X	X	X	X
Task 6, resp. *R. Norberg*, Risk sharing in pensions and life insurance	X	X			X	X	X	X	X	X

Tableau des livrables et des jalons / Deliverables and milestones			
Tasks	Title and substance of the deliverables and milestones	Delivery date, in months starting from T0	Partner in charge of the deliverable
0	Technical report	24	1
0	Final report	48	1
1	Technical report	12	2
1	Technical report	24	2
1	Technical report	36	2
1	Final report	48	2
2	Technical report	24	1
2	Final report	48	1
3	Technical report	24	2
3	Prototype for simulations	36	2
3	Final report	48	2
4	Technical report	24	1
4	Final report	48	1
5	Technical report	24	2
5	Presentation of implementations for simulation and estimations	36	2
5	Presentation of tests on real data	36	2
5	Final report	48	2
6	Technical Report	24	2
6	Final Report	48	2

4 Stratégie de valorisation, de protection et d'exploitation des résultats / Dissemination and exploitation of results. intellectual property

We intend to publish papers in international peer-reviewed journals and to present results in international conferences with review. We will develop a website of the project. We will present our conclusions to insurance companies, Institut des Actuaires, FFSA, CTIP, GEMA, relevant ministries, INSEE, pôle de compétitivité, etc. We will organize an international conference to disseminate results during the last year of the project.

The results obtained previously by project partners will remain their own respective property. Except the authorization to use previous knowledge which is the property of another project partner in view of the proper execution of the project, no right is granted on prior knowledge. In particular, some prior results may have undergone procedures of industrial protection. Specific results obtained by one partner only belong exclusively to that partner. Other partners will receive no grants on patents and related knowledge from the fact of the present project. The results obtained jointly by two or more partners will be the property of these partners, proportionally to their intellectual and financial contributions.

5 Description de l'equipe / Team description

5.1 Description, adéquation et complémentarité des participants / Partners description, relevance and complementarity

This ANR project brings together specialists in longevity risk (Boumezoued, El Karoui, Loisel, Planchet, Salhi), population dynamics (Bérard, El Karoui, Boumezoued), actuarial science and insurance risk management (Lefèvre, Loisel, Marceau, Milhaud, Norberg, Planchet, Robert, Rullière, Vedani), applied probability and math finance (Blanchet-Scalliet, Dorobantu, Eyraud-Loisel, Rosenbaum), food contaminants and epidemiology (Bertail, Lefèvre, Tressou), economics and long term interest rate risks (Rey-Fournier, Hillairet), semi-Markov models in insurance (Govorun, Planchet, Robert), statisticians (Bertail, Doukhan, Lopez, Pommeret, Rosenbaum), and numerical methods and advanced simulations (Bienvenüe, Lemaire, Pagès), in the combined endeavour to investigate **in an integrated way** important sources of risk, their representation, their estimation, the way they can be analyzed and numerically approximated or covered via advanced simulations and other techniques. The fact that many participants have experience and knowledge in several of the above mentioned areas is a strength of this project (even if it is not always mentioned above to be concise). The team benefits from the expertise of El Karoui, Hillairet, Loisel and Salhi on longevity thanks to the PhD theses of Bensusan, Salhi, and Boumezoued. Planchet supervises Q. Guibert on disability and long term care issues. Lemaire and Pagès have already a great experience on numerical methods and advanced simulation techniques. We will also benefit from external collaborations with researchers in medicine from Paris 6, from the Brain Institute in Paris on Alzheimer disability issues, and with Biffis (Imperial College) and Bauer (Georgia State University) on inter-generational aspects. The resumes of the participants with participation rate above 25% can be found in subsection 5.3. The resumes of the whole team are available online at http://isfaserveur.univ-lyon1.fr/~stephane.loisel/mini-cvs-LoLitA-team.pdf.

5.2 Qualification du coordinateur du projet / Qualification of the project coordinator

The project coordinator knows well every member of the project. He has already managed the research chair *Actuariat durable et stabilité du secteur de l'assurance à long term* (June 2010 - June 2013) whose objectives are already met. He has led a project of cooperation in training actuaries in several countries and a program of training of African professors (total budget obtained: 90000 euros). Besides, the project coordinator is very energetic and is extremely motivated by this project. He can also rely on a team of talented and recognized tasks coordinators to assist in the coordination at the task level, which is very important. He has strong links to the task coordinators: he has worked with Nicole El Karoui, Yahia Salhi, Alexandre Boumezoued and Caroline Hillairet on longevity. He has been invited several times in international conferences organized by Paul Doukhan. He knows very well Christian Robert and Mathieu Rosenbaum, and has several research projects in common with Ragnar Norberg.

5.3 Qualification, rôle et implication des participants / Qualification and contribution of each partner

S. Loisel is involved (at 10%) in another ANR proposal (2013) by Biard.
P. Doukhan is involved in an ERC proposal at 85% (2013 as well).
P. Bertail is involved in 2 other ANR proposals (2013), at 25% (Soulier) and at 10% (Chambaz).

Name	Partner	Status	Part. rate
Loisel	1	PR	80%
Berard	1	MCF	30%
Bertail	2	PR	30%
Bienvenue	1	MCF	20%
Blanchet-Scalliet	1	MCF	15%
Boumezoued	2	PhD student	100%
Dorobantu	1	MCF	15%
Doukhan	2	PR	15%
El Karoui	2	PR	60%
Eyraud-Loisel	1	MCF	20%
Govorun	1	PhD student	20%
Hillairet	2	MCF	50%
Lefevre	1	PR	20%
Lemaire	2	MCF	35%
Lopez	2	PR	35%
Marceau	1	PR	15%
Milhaud	2	MCF (equiv.)	20%
Norberg	1	Researcher (eq. DR)	40%
Pages	2	PR	35%
Planchet	1	PR	40%
Pommeret	1	PR	20%
Rey-Fournier	1	MCF	10%
Robert	1	PR	50%
Rosenbaum	2	PR	25%
Rulliere	1	MCF	20%
Salhi	1	MCF	20%
Tomas	1	Postdoc	50%
Tressou	2	CR	20%
Vedani	1	PhD Student	30%

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Professional experience, qualifications:

- 2012 *Habilitation à diriger les recherches*, Université Lyon 1
- 2002–2013 *Maître de conférences* (Lecturer), Université Lyon 1
- 1999–2002 *Allocataire-Moniteur*, Université Lyon 1
- 1998–2001 PhD in Mathematics, Université Lyon 1
- 1997–1998 *Agrégation de mathématiques*
- 1995–1999 Ecole Normale Supérieure de Lyon, Master's program in Mathematics

Research interests: Interacting Particle Systems, Stochastic Models in Biology, Monte Carlo Methods

PhD students: 1 supervision

Publications and working papers:

1. J. Bérard and L. Guéguen, *Accurate Estimation of Substitution Rates with Neighbor-Dependent Models in a Phylogenetic Context*, Systematic Biology (2012) 61(3): 510-521.
2. J. Bérard and J.B. Gouéré, *Survival probability of the branching random walk killed below a linear boundary*, Electronic Journal of Probability (2011) 16(14), 396–418.
3. J. Bérard and A. Ramírez, *Large deviations of the front in a one-dimensional model of* $X + Y \to 2X$, Annals of Probability (2010), 38(3): 955–1018.
4. J. Bérard and A. Ramírez, *Fluctuations of the front in a one-dimensional model for the spread of an infection*, preprint, `arXiv:math/1210.6781`
5. J. Bérard and A. Huet, *Sequential Monte Carlo methods for neighbor-dependent nucleotide substitution models*, In Preparation

Patrice BERTAIL

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Current position: Professor, first clas (contingent CNU 2008), Université Paris Ouest-Nanterre-La Défense.

E-mail: `patrice.bertail@gmail.com`

Professional experience, qualification: In charge of speciality "Statistique du Risque" of ISIFAR Master Degree (Ingénierie Statistique et Informatique de la Finance, de l'Assurance et du Risque), 2007-2011, Paris VII and Paris Ouest.

Research interests: Resampling, bootstrap, jackknife, subsampling. Empirical likelihood methods and generalisations to empirical divergence. Time series and homogeneous random fields, non-stationarity (unit root tests, cointegration, null recurrence). Markov chains. Efficiency bounds and semi-parametric estimation: generalization to time series. Empirical processes indexed by classes of functions and applications to statistical learning. Statistical methods for risk measurement: extreme value theory, VaR, ... Applications to food and chemical contaminants, industrial risks (nuclear, environmental) and insurance.

Publications and working papers:

1. Bertail, P. , Gauthérat E. et Harari-Kermadec (2008). Exponential bounds for self normalized sums, *Electronic Communications in Probability*, **13**, paper 57, 628-640.
2. Bertail, P., Clémençon S., Tressou, J. (2009). Extreme values statistics for Markov chains via the (pseudo-) regenerative method, *Extremes*, 12, Number 4, Pages 327-360
3. Bertail, P., Clémençon S. et J. Tressou (2010). Statistical analysis of a dynamic model for food contaminant exposure with applications to dietary methylmercury contamination. *Journal of Biological Dynamics*, 4(2), 212-234.

4. Bertail, P. , Clémençon, S. (2009) et (2010). Sharp Bounds for the Tails of Functionals of Markov Chains, Probability Theory and its applications, *Theory Probab. Appl.*, Volume 54, Issue 3, pp. 505-515.
5. Bertail, P., Clémençon S.(2011). A renewal approach to U-statistics for Markovian data, *Mathematical Methods of Statistics*, Vol. 20, No. 2. pp. 79-105.

Christophette BLANCHET-SCALLIET

Age, situation: 37 years, female, married, three children

Current position: *Maître de Conférences* (Associate Professor) at Ecole Centrale de Lyon since September 2007, Institut Camille Jordan (UMR 5208)

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Professional experience, qualifications:

2002–2007 *Maitre de Conférences* at University of Nice, Laboratoire Dieudonné (UMR 7351)

2001–2002 *ATER* (assistant professor) at University of Evry

1998–2001 *Allocataire-Moniteur* (assistant professor) at University of Evry

PhD Thesis, in applied mathematics, Laboratoire d'Analyse et Probabilités, Université d'Evry

1997–1998 DEA in mathematics, Université Rennes 1, *Agrégation de mathématiques*

1997–1999 Ecole Normale Supérieure de Cachan

Research interests: Enlargement of Filtrations, Backward Stochastic Differential Equations, Stochastic Optimal Control and Hamilton-Jacobi- Bellman equations, Default risk models, Counterparty Risk.

Publications and working papers:

1. C. Blanchet-Scalliet; D. Dorobantu; D. Rullière*The density of the ruin time for a renewal-reward process perturbed by a diffusion* Applied Mathematics Letters, http://dx.doi.org/10.1016/j.aml.2012.04.003, 2013, 26 (1), Pages 108-112
2. S. Ankirchner, C. Blanchet-Scalliet; A. Eyraud-Loisel *Optimal liquidation under directionnal views and additionnal information.* submitted Sep. 2012
3. C. Blanchet-Scalliet; F. Patras *Structural Counterparty Risk Valuation for Credit Default Swaps* Credit Risk Frontiers: Subprime Crisis, Pricing and Hedging, CVA, MBS, Ratings, and Liquidity, WILEY, pp. 437-456, 2011
4. S. Ankirchner; C. Blanchet-Scalliet; A. Eyraud-Loisel *Credit Risk Premia And Quadratic's BSDEs with a single jump* International Journal of Theoretical and Applied Finance (IJTAF), 2010, 13 (7), pp. 1103-1129
5. C. Blanchet-Scalliet; A. Eyraud-Loisel; M. Royer-Carenzi *Hedging of Defaultable Contingent Claims using BSDE with uncertain time horizon.* Le bulletin français d'actuariat, 2010, 20 (10), http://www.institutdesactuaires.com/bfa/

Alexandre BOUMEZOUED

Age, situation: 24 years, male, cohabiting

Current position: *Allocataire-moniteur* (Assistant Professor) since October 2012; PhD student in Applied Mathematics at Université Paris 6, Laboratoire de Probabilités et Modèles Aléatoires (LPMA, Paris 6), Laboratoire de Science Actuarielle et Financière (SAF, Lyon 1) – Advisors : Nicole El Karoui (LPMA) and Stéphane Loisel (SAF)

E-mail: alexandre.boumezoued@upmc.fr

Professional experience, qualifications:

2011–2012 Master 2 in Probability Theory, Université Paris 6; French Engineer Diploma, École des Ponts ParisTech Applied Mathematics and Computer Science

2010–2011 One-year Internship in R&D Actuarial Department (Milliman France)

2008–2010 Two years at École des Ponts ParisTech French Engineer School in Marne-la-Vallée

Research interests: Actuarial and Financial Mathematics, Longevity Risk Modeling, Dynamic Population Models, Point Processes, Numerical Probability, Pricing and Hedging of Longevity Derivatives.

Reviewal responsibilities: Referee for Methodology and Computing in Applied Probability (MCAP).

Publications and working papers:

1. A. Boumezoued, Master's Thesis, *Numerical Methods for Dynamic Population Models*, 2012. Advisors : Nicole El Karoui and Stéphane Loisel.
2. A. Boumezoued, Y. Angoua, L. Devineau, J.-P. Boisseau *One-year reserve risk including a tail factor: closed formula and bootstrap approaches*, 2011. http://hal.archives-ouvertes.fr/hal-00605329/

Diana DOROBANTU

Age, situation: 35 years, female, two children

Current position: *Maître de Conférences* (Associate Professor) at Université Lyon 1 since September 2008, Laboratoire de Sciences Actuarielle et Financière

E-mail: `diana.dorobantu@univ-lyon1.fr`

Professional experience, qualifications:

2007–2008 ATER (Assistant Professor) at Université Toulouse 1

2004–2007 *Allocataire-Moniteur* (Assistant Professor), Université Toulouse 3; PhD Thesis in Applied Mathematics; Laboratoire de Statistiques et Probabilités, Université Toulouse 3

2003–2004 Master 2 in Applied Mathematics, Université Toulouse 3

2002–2003 Master 2 of International Business and Law, Universitatea Bucuresti-Université Paris 1

1998–2002 Academia de studii economice Bucuresti (Roumanie), Master in Finance and Banking

1996–2000 Universitatea Bucuresti, Master in Theoretical and Applied Mathematics

Research interests: Credit risk, Asymmetrical information, Optimal stopping problems, Hitting time law for jump processes

Publications and working papers:

1. D. Dorobantu, M. Mancino, M. Pontier *Optimal strategies in a risky debt context*, Stochastics, Vol. 81, Nos. 3-4, 2009, 269-277
2. L. Coutin, D. Dorobantu *First passage time law for some Lévy processes with compound Poisson: existence of a density*, Bernoulli 17 (4), 2011, 1127-1135
3. D. Dorobantu *Optimal stopping for Markov processes and decreasing affine functions*, Romanian Journal of Pure and Applied Mathematics, 56, No.4, 2011, 283-294
4. C. Blanchet-Scalliet, D. Dorobantu, D. Rulliere *The density of a passage time for a renewal-reward process perturbed by a diffusion*, Applied Mathematics Letters, volume 26, issue 1, 2013, 108-112
5. A. Cousin, D. Dorobantu, D. Rulliere *An extension of Davis and Lo's contagion model*, to appear in Quantitative Finance

Paul DOUKHAN

Age, situation: 57 years, male, married, two children

Current position: *Professor* (PrEx, échelon 2) at Université Cergy-Pontoise since September 1993, Laboratoire d'Analyse Géométrie et Modélisation (AGM, UMR 8088)

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Professional experience, qualifications:

- 2002-2008 Professor of statistics, ENSAE
- 1982–1993 Full time researcher CNRS, Orsay
- 1988–1989 Professor of mathematics: university of Wuhan, China
- 1986 HDR: Study of mixing processes, advisor: D. Dacunha-Castelle, Orsay
- 1980 PhD: Nonlinear autoregressive models, advisor: J. Bretagnolle, Orsay
- 1975–1979 Ecole Normale Supérieure, Saint-Cloud
- 1978 *Agrégation de mathématiques* rank 11th
- 1976 Master of Statistics, Orsay

Research interests: Weak dependence concepts, long-range dependence, non-parametric statistics, empirical processes, limit theorems in probability, applications of dependence.

Coordination of research programs: 1986-1994 Responsible of cooperation project with Venezuela; 2010-2012 Research program DNIPRO with Kiev Polytechnic Institute; 2012 Thematic year on non-stationarity and risk management in Cergy-Pontoise, with Jean Luc Prigent and Flora Koukiou.

Editorial responsibilities: Associated Editor of Stochastic Processes and their Applications, Statistics, Stapro online encyclopedia, Stochastic Processes-Kiev

Awards: 2011, Senior Member IUF, French Universitary Institute

PhD students: 15 PhD supervised students

Publications and working papers:

1. P. Doukhan, *Mixing: properties and examples,* LNS 85, Springer Verlag (1994)
2. P. Doukhan, S. Louhichi, *A new weak dependence condition and applications to moment inequalities.* Stochastic Process. Appl. 84-2, 313-342 (1999)
3. P. Doukhan, G. Oppenheim and M. S. Taqqu, *editors*. *Theory and Applications of Long-range Dependence,* Birkhauser, Boston (2003)
4. P. Doukhan, G. Lang, C. Prieur, S. Louhichi, J. Dedecker, J. R. León, *Weak dependence: models, theory and applications,* LNS 190, Springer-Verlag (2007)
5. P. Doukhan, S. Prohl, C. Y. Robert, *Subsampling weakly dependent times series and application to extremes.* Discussion Paper TEST 20-3, 447-502 (2012)

Nicole EL KAROUI-SCHVARTZ

Age, situation: 69 years, female, married, five children

Current position: *Professor* at UPMC (Paris VI) since September 2008, Laboratoire de Probabilité et Modèles alátoires.

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Professional experience, qualifications:

- 2008– *Professor* at LPMA, UPMC, Paris
- 1997–2008 Full time Professor at Ecole Polytechnique.
- 1988–1997 Professor at Paris VI University-UPMC
- 1979–1988 Professor at ENS Fontenay
- 1973–1979 Professor at Université du Maine (Le Mans).
- 1968–1973 Assistant-Professor at Univ. Orsay
- 1968–1971 PhD Thesis Thèse de Doctorat d'Etat, Paris.
- 1964-1968 Ecole Normale Supérieure (Sèvres).

Research interests: Longevity Modelling, Micro-macro simulation, Long term interest rate, Mathematical Finance, Portfolio optimization, Risk measures, Credit Risk, Forward Utility, Backward stochastic differential equations.

PhD students: 7, including: *Kazi Tani Nabil* (Dec 2012): Construction de mesures de risques dynamiques. *Nguyen Trung Lap* (Sept 2012): Variable Annuities. *Camillier Isabelle* (Juin 2010): Long Term Interest rates. Determinantal point processes. *Bensusan Harry* (2010): Modélisation dynamique de la longévité et Applications aux produits dérivés.

Conferences as Invited or Plenary Speaker: International Congress Probability Statistics, Istambul July 2012, Medaillon Lecture; European Conference Mathematics for Innovation Tokyo Fevrier 2012; Mathematical Finance, Fields Institute, Janvier 2010; ICI Applied Mathematics International Congress, Zurich, Juillet 2007; September 2002 - (Kyoto) International Conference in honor of Pr K. Itô ; Aug 2002: Invited Speaker at International Congress of Mathematicians Beijing.

Publications and working papers:

1. El Karoui.N, M'rad.M An Exact Connection between two solvable SDEs and a Nonlinear Utility Stochastic PDE *revision SIAM Journal Financial Mathematics*(2012)
2. Barrieu. P, El Karoui. N, (2012) Monotone stability of quadratic semimartingales with applications to unbounded general quadratic BSDEs. *Annals of Probability, 2013* (Accepted Jan 2012)
3. Barrieu. P, Bensusan. H, El Karoui. N, Hillairet. C, Loisel. S, Ravanelli. C and Sahli. Y, (2012) Understanding, modeling and managing longevity risk: aims and scope *Scandinavian Actuarial Journa* Volume 2012, Issue 3, (2012) 203-231.
4. El Karoui, N. Jeanblanc, M. Jiao, Y. (2010) What happens after a default : the conditional density approach. *Stochastic Processes and their Applications*, 120(7), 1011-1032, 2010.

Maria GOVORUN

Age, situation: 28 years, female, single

Current position: *PhD student* at Université libre de Bruxelles since September 2009, Faculté des sciences.

E-mail: `mgovorun@ulb.ac.be`

Professional experience, qualifications:

2009–Present	Université libre de Bruxelles, PhD student
2008-Present	Full member of International Actuarial Association, Full member of Russian Guild of Actuaries
2008–2009	AIG Life Russia Insurance Company, actuary
2008–2009	State University Higher School of Economics, Moscow, Risk Management Lab, junior researcher
2005–2009	Actuarial&Financial Services Limited, leading actuary
2006–2008	State University Higher School of Economics, Moscow, Master in economics, risk management and actuarial methods
2001–2006	Lomonosov Moscow State University, Moscow, Master in applied mathematics and informatics

Research interests: Development of phase-type methods in actuarial science, Markov chains, fluid queues, pension insurance, health care, disability models, longevity risk, optimal consumption, health economics.

Publications and working papers:

1. M. Govorun *High-frequency financial data analysis as applied to hedging problem of European type options*, The collection of best theses 2006, Moscow State University press, 2006
2. M.Govorun, G.Latouche, M.-A. Remiche, *Stability for fluid queues: characteristic inequalities*, to appear in Stochastic Models, 2012
3. M.Govorun, G.Latouche, M.-A. Remiche, *Profits and risks of pension plans*, Performance Evaluation Review, 39: 41, 2012.
4. M.Govorun, G.Latouche, M.-A. Remiche *Profit-test model for pension funds using Matrix- Anatytic Modeling*, proceedings of the Actuarial and Financial Mathematics Conference – Interplay Between Finance and Insurance, p. 87-94, Brussels, 2011.
5. M.Govorun, G.Latouche *Modeling the effect of health: phase-type approach*, submitted
6. M.Govorun, G.Latouche, S.Loisel, *A phase-type look at health care costs*, in progress

Caroline HILLAIRET

Age, situation: 35 years, female, married, two childs

Current position: *Maître de Conférences* (Associate Professor) at Ecole Polytechnique since September 2005, CMAP (Centre de Mathématiques Appliquées) UMR 7641

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Professional experience, qualifications:

2004–2005 ATER, Université Toulouse 3.

2001–2004 *Allocataire-Moniteur* at Université Toulouse 3; PhD Thesis, Laboratoire de Statistique et Probabilités.

2000–2001 DEA in Applied Mathematics.

1999–2000 *Agrégation externe de Mathématiques*.

Research interests: Longevity, Long term interest rates, Credit Risk, Asymmetric information, Enlargement of Filtrations.

Publications and working papers:

1. P. Barrieu, H. Bensusan, N. El Karoui, C. Hillairet, S. Loisel, C. Ravanelli, Y. Salhi *Understanding, Modeling and Managing Longevity Risk : Key issues and Main Challenges*, Scandinavian Actuarial Journal (2012), Vol. 2012, No 3, 203-231.
2. C. Hillairet, Y. Jiao *Credit Risk with asymmetric information on the default threshold*, Stochastics: An International Journal of Probability and Stochastic Processes, (2012) Vol. 84, Nos. 2-3, 135.
3. C. Hillairet, Y. Jiao *Information Asymmetry in Pricing of Credit Derivatives* International Journal of Theoretical and Applied Finance Vol. 14, No. 5 (2011) 611-633.
4. C. Hillairet *Comparison of insiders' optimal strategies depending on the type of side-information*, Stochastic Processes and Their Applications 115 (2005) 1603-1627.
5. C. Hillairet *Existence of an equilibrium on a financial market with discontinuous prices, asymmetric information and non trivial initial sigma-fields*, Mathematical Finance, (2012) Vol. 15, No 1, 99-117.

Vincent LEMAIRE

Age, situation: 34 years, male, one child

Current position: *Maître de Conférences* (Associate Professor) Université Pierre et Marie Curie UPMC Paris 06, Laboratoire Probabilités et Modèles Aléatoires, UMR 7599.

E-mail: vincent.lemaire@upmc.fr **Web:** http://proba.jussieu.fr/~lemaire

Professional experience, qualifications:

2001–2005 *Allocataire-Moniteur* (assistant professor), PhD Thesis, in applied mathematics, Laboratoire de d'Analyse et de Mathématiques Appliquées, Université Paris Est Marne-la-Vallée

2000–2001 Master 2 in Mathématiques Appliquées, Université Paris Est Marne-la-Vallée

Research interests: Numerical Probability, Monte Carlo methods, Discretization schemes, Stochastic algorithms, Exact simulation, Longtime numerical approximation, Energy price modelling.

Publications and working papers:

1. Vincent Lemaire and Gilles Pagès. *Unconstrained recursive importance sampling,* Ann. Appl. Probab., 20(3):1029–1067, 2010.
2. Vincent Lemaire and Stephane Menozzi. *On some Non Asymptotic Bounds for the Euler Scheme,* Electronic Journal of Probability, 15:1645–1681, 2010.
3. Noufel Frikha and Vincent Lemaire. *Joint Modelling of Gas and Electricity spot prices*, Applied Mathematical Finance, DOI:10.1080/1350486X.2012.658220.
4. Vincent Lemaire. *An adaptive scheme for the approximation of dissipative systems,* Stochastic Processes and their Applications, 117(10):1491–1518, 2007.
5. Vincent Lemaire. *Behavior of the Euler scheme with decreasing step in a degenerate situation,* ESAIM. Probability and Statistics, 11:236–247, 2007.

Stéphane LOISEL

Age, situation: 34 years, male, married, two children

Current position: *Professor* at Université Lyon 1 since September 2011.

E-mail: `loisel@univ-lyon1.fr` **Web:** `http://isfaserveur.univ-lyon1.fr/~stephane.loisel/`

Professional experience, qualifications:

- 2009-2012 Associate researcher at CMAP, Ecole Polytechnique, Palaiseau, France (2009-2012). Research expert on longevity risk in the Chair "Derivatives of the future", sponsored by the French Federation of Banks and chaired by Nicole El Karoui.
- 2010 Habilitation thesis (HDR)
- 2005–2011 Maître de Conférences, Université Lyon 1
- 2002–2005 PhD Thesis in applied mathematics, Université Lyon 1
- 2001 *Agrégation de mathématiques*
- 1998-2002 Ecole Normale Supérieur de Lyon, éléve normalien, mathematics.

Research interests: Longevity: longevity risk, stochastic mortality, pandemic risk, basis risk. Risk theory: ruin probabilities, hitting times, multidimensional processes, stochastic dependence, Markovian environment. Acceleration of nested simulations. Solvency II, behavioral risk, Economic Capital and Entreprise Risk Management.

Coordination of research programs: Coordinator of research chair *Actuariat Durable*, June 2010-June 2013.

Editorial responsibilities: Associate Editor of Insurance:Mathematics and Economics, Methodology and Computing in Applied Probability, American Journal of Algorithms and Computing, Risks, and Bulletin Français d'Actuariat (BFA). Co-editor of European Actuarial Journal.

Awards and invitations: Best paper award, Conference of the Life Section of the International Actuarial Association, Mexico, Oct. 2012; Second best paper award, ASTIN Colloquium, Mexico, Oct. 2012; Corresponding member of the Swiss Actuarial Association (2012); 2011 Lloyd's Science of Risk: runner-up prize in the insurance and finance category; SCOR 2005 Award (best PhD in Actuarial Science). 15 international conferences as invited speaker. Invited for research stays in UNSW (Sydney), UdM (Montréal), Laval (Québec), GSU (Atlanta), ULB (Brussels), LSE (London), UNIL (Lausanne), HKU (Hong Kong), METU (Ankara), Cornell and Columbia U. (Spring 2013).

PhD students: 12 PhD supervised students (5 defended, 7 in progress (including 2 who defend by April 2013)).

Publications and working papers:

1. Y. Salhi, S. Loisel, Longevity basis risk modeling: a co-integration based approach, Working paper (2012) available on Hal preprint server.
2. P. Barrieu, H. Bensusan, N. El Karoui, C. Hillairet, S. Loisel, C. Ravanelli, Y. Salhi, *Understanding, modelling and managing longevity risk: key issues and main challenges*, Scandinavian Actuarial Journal (2012), Vol. 2012, No 3, 203-231.
3. C. Lefèvre, S. Loisel, On multiply monotone distributions, continuous or discrete, with applications, accepted (2012), to appear in Journal of Applied Probability.
4. S. Loisel, X. Milhaud, *From deterministic to stochastic surrender risk models: impact of correlation crises on economic capital*, European Journal of Operational Research (2011), Vol. 214, No 2, 348-357.
5. M. Chauvigny, L. Devineau, S. Loisel, V. Maume-Deschamps, *Fast remote but not extreme quantiles with multiple factors. Applications to Solvency II and Enterprise Risk Management*, European Actuarial Journal (2011), Vol. 1, No 1, 131-157.
6. S. Loisel, N. Privault, *Sensitivity analysis and density estimation for finite-time ruin probabilities*, Journal of Computational and Applied Mathematics, Vol. 230, No 1, 107-120 (2009).

Olivier LOPEZ

Age, situation: 32 years, male, married, one child

Current position: *Maître de Conférences* (Associate Professor) at Université Pierre et Marie Curie Paris VI since September 2008, Laboratoire de Statistique Théorique et Appliquée (Équipe d'accueil 3124)

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Professional experience, qualifications:

- 2009-2011 Actuarial Diploma, Centre d'Etudes Actuarielles, Paris.
- 2008 *Post-doctoral position*, WIAS, Berlin.
- 2005–2008 *Allocataire-Moniteur* (assistant professor) at ENSAI and Université Rennes 1; PhD Thesis, in applied mathematics, CREST-ENSAI and IRMAR, Université Rennes 1
- 2004–2005 Master 2 in Statistics, Rennes 1
- 2003–2004 *Agrégation de mathématiques*
- 2001–2005 Ecole Normale Supérieure de Cachan, Department of Mathematics-Informatics, Rennes.

Research interests: Survival analysis, nonparametric and semiparametric regression, change-point analysis, bivariate censoring, recurrent events, dimension reduction, nonparametric goodness-of-fit testing.

Editorial responsibilities: Associate editor of Bulletin Français d'Actuariat

PhD students: co-supervision of A. Oueslati (SNCF and Université Pierre et Marie Curie), and S. Gribkova (Université Pierre et Marie Curie)

Publications and working papers:

1. O. Lopez, V. Patilea, *Nonparametric lack-of-fit tests for parametric mean-regression models with censored data*, Journal of Multivariate Analysis, Volume 100, Issue 1, January 2009, Pages 210-230 Stochastic Processes and their Applications, vol 115/11 pp 1745-1763, January 2009
2. O.Lopez, *Single-index regression models with right-censored responses, Journal of Statistical Planning and Inference, Volume 139, Issue 3, 1 March 2009, Pages 1082-1097*
3. *O. Bouaziz, O. Lopez, Conditional density estimation in a censored single-index regression model, Bernoulli, Volume 16, Issue 2, 2010, Pages 514-542*
4. *O. Lopez A generalization of Kaplan-Meier estimator for analyzing bivariate mortality under right-censoring and left-truncation with applications to model-checking for survival copula models, Insurance: Mathematics and Economics, Volume 51, Issue 3, 2012, Pages 505-516*
5. *O. Lopez, A. Oueslati A proportional hazards regression model with change-points in the baseline function, Lifetime Data Analysis, 2012 (in press).*

Etienne MARCEAU

Age, situation: 46 years, male, 2 children

Current position: *Professeur titulaire* (Full Professor) at Université Laval, école d'actuariat.

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Professional experience, qualifications:

- 2005– *Professeur invité* (Invited Professor), Université Lyon 1
- 2004–2005 Professeur invité (Invited Professor), Université Catholique de Louvain
- 1996–2000 Professeur adjoint (Assistant Professor), Université Laval.
- 1994–1996 Ph.D. Thesis in actuarial science, Université Catholique de Louvain
- 1991–1993 Masters in Actuarial Science, Université Laval

Research interests: Risk Theory, Ruin Theory, Dependence Models in Actuarial Science, Stochastic Mortality and Longevity Risk, Risk Models in Actuarial Science, Investment Models in Actuarial Science, Actuarial Mathematics in Life, Group, and Non-Life Insurance, Actuarial Mathematics in Pension, Statistics in Actuarial Science.

Coordination of research programs: Supervisor of 8 PhD students, incl. 3 in progress.

Tasks in refereed journals: Associate Editor of Insurance:Mathematics and Economics

Awards: Invited Speakers in 15 international conferences and research seminars in the last 6 years. Grants from CRSNG, from SOA-CAS, from FQRNT

Publications and working papers:

1. Cossette, H., Delwarde, A., Denuit, M., Guillot, F. and E. Marceau (2007). *Pension plan valuation and dynamic mortality tables*, North American Actuarial Journal 11 (2), 1-34..
2. Marceau, E. (2013). *Modélisation et évaluation des risques en sciences actuarielles*. Springer-Verlag France. 486 pages.
3. Cossette, H., Mailhot, M. and E. Marceau (2012). *T-Var based capital allocation for multivariate compound distributions*, Insurance: Mathematics and Economics 50(2), 247-256.
4. Bargès, M., Cossette, H., Loisel, S. and E. Marceau. (2011). *Discounted aggregate claims with dependence*, ASTIN Bulletin 41(1), 215-238.

Xavier MILHAUD

Age, situation: 27 years, male

Current position: *responsible for the actuarial department* at ENSAE ParisTech since September 2011, Centre de Recherche en Economie et Statistique (LFA lab).

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Professional experience, qualifications:

- 2011–2012 *Teaching assistant* (responsible for the actuarial department) at ENSAE ParisTech
- 2009–2012 PhD Thesis in applied mathematics (CIFRE partnership with AXA Global Life), Laboratoire de Science Actuarielle et Financière, Université Lyon 1
- 2009–2011 Actuarial Diploma, Institut de Science Financière et d'assurances, Lyon 1
- 2007–2008 Research Master in Financial and Actuarial Sciences, Université Lyon 1
- 2005–2008 Engineer Diploma at ENSIMAG, option *financial mathematics*

Research interests: Generalized linear models, Survival analysis, Model selection, Behaviour modelling, Classification algorithms, Mixture models, Hidden Markov models.

Coordination of research programs: Supervisor of research and actuarial memoirs at ENSAE ParisTech.

Tasks in refereed journals: reviewed publications in EJOR, EUAJ, BFA.

Awards: Best paper of the ASTIN-AFIR-IAALS congress (Mexico 2012), section IAALS. Runner-up of the Lloyd's Science of Risk Prize 2011 (with Stéphane Loisel).

Publications and working papers:

1. Milhaud, X. *Selection of GLM mixtures: a new criterion for clustering purpose*, submitted (2012).
2. Milhaud, X. *Exogenous and endogenous risk factors management to predict surrender behaviours*, submitted (2012).
3. Loisel, S., Milhaud, X. *From deterministic to stochastic surrender risk models: impact of correlation crises on economic capital*, European Journal of Operational Research, vol 214, pp 348-357 (2011).
4. Milhaud, X., Maume-Deschamps, V., Loisel, S., *Surrender triggers in Life Insurance: what main features affect the surrender behavior in a classical economic context?*, Bulletin Français d'Actuariat, vol 22 pp 5-48 (2011).
5. Milhaud, X., Gonon, M-P. et Loisel, S. *Les comportements de rachat en Assurance Vie en régime de croisière et en période de crise*, Risques, vol. 83 pp 75-80 (2010).

Ragnar NORBERG

Age, situation: 67 years, male, married, two children

Current position: *Research Officer (Chercheur)*, ISFA, Université Lyon 1; *Emeritus Professor* London School of Economics.

E-mail: `ragnar.norberg@univ-lyon1.fr` **Web:** `http://isfa.univ-lyon1.fr/~norberg/`

Professional experience, qualifications:

- 2000–2010 *Professor of Statistics*, London School of Economics
- 1991–2000 *Professor of insurance mathematics*, University of Copenhagen
- 1984–1991 *Professor of Statistics with Insurance Mathematics*, University of Oslo
- 1971-1984 *Research Assistant, Associate Professor*, University of Oslo
- 1981-1982 *Guest Professor*, ETH Zürich

Research interests: Insurance mathematics (life, non-life, risk theory), financial mathematics, and related topics in statistics and probability.

Scientific Committees in major international conferences 2007 - present: Cramér symposium Stockholm 2013; *Afmath* Brussels 2009, 2010, 2011, 2012, 2013; *4th Brazil. Conf. Insurance and Finance* 2009; *Bachelier World Congress* London 2008.

Invited key-note lectures in major international conferences 2007 - present: *QMF* Cairns 2012; *Recent Devel. in Math. Fin.* Stockholm 2011; *QMF* Sydney 2010; *Afmath* Brussels 2010; *IFID/MITACS Fields Inst.* Toronto 2008; *AFIR Coll.* Stockholm 2008; *IME Conference* Piraeus Greece 2007; *AFIR Coll.* Stockholm 2007.

Editorial responsibilities: Assoc. Editor *Fin. & Stoch.*; Assoc. Editor *IME*.

PhD students: 60 MSc theses, 9 PhD theses

Publications and working papers:

1. Norberg, R.: *Quadratic hedging of payments streams.* 20 pp. Submitted to *European Actuarial Journal*
2. Norberg, R., Savina, O. (2012): A quadratic hedging approach to comparison of catastrophe indices. *International Journal of Theoretical and Applied Finance*. **15** (*4*), DOI 10.1142/S0219024912500306
3. Norberg, R. (2012): Optimal hedging of demographic risk in life insurance. *Finance and Stochastics* 2012, DOI 10.1007/s00780-012-0182-3
4. Constantinescu, C., Maume-Deschamps, V., Norberg, R. (2012): Risk processes with dependence and premium adjusted to solvency targets. *European Actuarial Journal* **2** *1* 1-20, DOI 10.1007/s13385-012-0046-4
5. Norberg, R. (2010): Forward mortality and other vital rates – are they the way forward? *Insurance: Mathematics and Economics.* **47**, 105-112

Gilles PAGÈS

Age, situation: 52 years, male

Current position: *Professeur* (Full Professor) at UPMC since September 2001, Laboratoire de Probabiltés et Modèles Aléatoires (LPMA, UMR 7599)

E-mail: `gilles.pages@upmc.fr` **Web:** `http://www.proba.jussieu.fr/pageperso/pages/`

Professional experience, qualifications:

- 2009– Director of the LPMA.
- 2001– Co-head of the Master “Probbailités & Finance”, UPMC-École Polytechnique.
- 2001– Professor (Probability, Numerical probability, Financial Mathematics), UPMC.
- 1993–2001 Professor, Univ. Paris 12-Créteil.
- 1988–1993 Maître de Conférences, Univ. Paris I.

Research interests: Limit theorems for semi-martingales, Monte Carlo & quasi-Monte Carlo method, Variance reduction, Discretization of processes, Optimal quantization, functional quantization, energy markets, American options, Optimal stopping, (Reflected)-Backward Stochastic Differential Equations, Stochastic Approximation, long run behaviour of dynamical systems.

Coordination of research programs: ACI FIN' Quant (2005-2009), CRIS project (FUI, 2008-11), Azzurrisk project (FUI, 20010-2013, co-head with H. Pham)

Editorial responsibilities: Editor of *Mathematics of Computation*, *Bernoulli* (start 01.2013), *ESAIM P&S* (and editor in-chief, start 01.2013)

PhD students: 11 PHD students supervised (Ben Alaya, Attali, Cohort, Schmidt, Lemaire, Panloup, Sellami, Sagna, Frikha, Laruelle, Illand), 2 are in progress (Yu, Fernandez)

Publications and working papers:

1. G. Pagès, B. Wilbertz, Intrinsic stationarity for vector quantization: Foundation of dual quantization, *SIAM J. on Numerical Analysis*, **50**:747-780, 2012
2. S. Graf, H. Luschgy, G. Pagès, The local quantization behaviour of absolutely continuous probabilities, *Annals of Probability*, **40**(4):1795-1828, 2012.
3. F. Panloup, G. Pagès, Ergodic approximation of the distribution of a stationary diffusion : rate of convergence, *Annals of Applied Probability*, **22**(3) :1059-1100, 2012.
4. V. Lemaire, G. Pagès, Unconstrained Recursive Importance sampling, *Annals of Applied Probability*, **20**(3):1029-1067, 2010.
5. G. Pagès, A. Sellami, Convergence of multi-dimensional quantized SDEÕs, *Séminaire de Probabilités XLIII* (C. Donati-Martin, A. Lejay, A. Rouault eds), Springer, Berlin, 269-308, 2011.

Frédéric PLANCHET

Age, situation: 45 years, male, married, two children

Current position: *Professeur* (Full time Professor) at Université Lyon 1 since September 2003, Laboratoire de Sciences Actuarielle et Financière (équipe d'accueil 2429)

E-mail: frederic.planchet@univ-lyon1.fr **Web:** http://www.ressources-actuarielles.net

Professional experience, qualifications:

1991–2012 *Actuaire associé* (Partner actuary) at WINTER & Associés

– HDR in actuarial sciences
– PhD Thesis, in actuarial sciences

Research interests: Solvency II (Pillars 1 and 2), IFRS, MCEV : internal models, ORSA quantitative models, market consistent valuations, economic scenario generators (both risk-neutral and historical views) - Modeling censored and truncated data (mortality, disability, lapse, etc.) : best-estimate assumptions for reserve calculations, longevity risk evaluation, catastrophic risk in life insurance - Stochastic models and simulation techniques : best estimate and SCR calculation, both in standard model and internal model ; time optimization for Monte-Carlo methods. - Liabilities valorization and asset-liability management in life insurance.

Publications and working papers:

1. Guibert Q., Juillard M., Planchet F. [2012] Measuring Uncertainty of Solvency Coverage Ratio in ORSA for Non-Life Insurance, *European Actuarial Journal*, 2:205-226, doi: 10.1007/s13385-012-0051-7.
2. Nteukam-T. O., Planchet F., Thérond P.E. [2011] Optimal strategies of hedging portfolio of unit-linked life insurance contracts with minimum death guarantee, *Insurance: Mathematics and Economics*, Vol. 48, Issue 2, pp. 161-175.
3. Planchet F. [2012] Modélisation du risque de pandémie dans Solvabilité 2, *Assurances et gestion des risques*, To appear.
4. Nteukam-T. O., Planchet F. [2012] Stochastic Evaluation of Life Insurance Contract: Model Point on Asset Trajectories & Measurement of the Error Related to Aggregation, *Insurance: Mathematics and Economics*. Vol. 51, pp. 624-631.
5. Kamega A., Planchet F. [2013] Construction de tables de mortalité prospectives sur un groupe restreint : mesure du risque d'estimation, *Bulletin Français d'Actuariat*, vol. 13, no25.

Denys POMMERET

Age, situation: 44 years, male, married, three childs

Current position: Professor at Aix Marseille University since September 2006, Institute of Mathematic of Luminy.

E-mail: denys.pommeret@univ-amu.fr **Web:** http://iml.univ-mrs.fr/~pommeret/

Professional experience, qualifications:

- 1999–2006 *Assistant professor* at ENSAI, Rennes
- 2004 *Habilitation à Diriger de Recherches*, Rennes University II.
- 1996–1999 Assistant professor, ENITIAA, Nantes
- 1995–1996 Contract assistan Professor, Toulouse, Paul Sabatier University
- 1992–1995 PhD Thesis, in applied mathematics, Toulouse, Paul Sabatier University

Research interests: Goodness of-fit-test, Bayesian statistics, latent variables.

Coordination of research programs: Head of the Statistical Team at the Institute of Mathematics of Luminy, Responsible of the 42th congress of the French Statistical Society.

PhD students: 3 PhD supervised students.

Publications and working papers:

1. Baragatti, A. Grimaud, D. Pommeret, (2012) *Likelihood-free parallel tempering*, Statistics and Computing, DOI 10.1007/s11222-012-9328-6.
2. Druilhet, P. Pommeret, D. (2012) *Invariant conjugate analysis for exponential families*, Bayesian Analysis, 7, 903–916.
3. Baragatti, M. Grimaud, A. Pommeret, D. (2012) *Parallel tempering with Equi-Energy moves*, Statistics and Computing, DOI 10.1007/s11222-012-9313-0.
4. Baragatti, M. Pommeret, D. (2011) *Ridge parameter for g-prior distribution in probit mixed model*, Computational Statistics and Data Analysis, 56, 1920–1934.
5. Baragatti, M. Pommeret, D. (2011) *Comments on Bayesian variable selection for disease classification using gene expression data*, Bioinformatics, 27:1194.
6. Pommeret, D. (2011) *Data driven smooth test for contaminated data*, Journal of Statistical Theory and Practice, 5(4)
7. Ghattas, B. Pommeret, D. Reboul, L. Yao, A.F. (2011) *Data driven smooth test for paired populations*, Journal of Statistical Planning and Inference, 141 (1) 262-275
8. Pommeret, D. (2010) *Testing Mixed Distributions when the Mixing Distribution Is Known*, Advances in Data Analysis, Data Handling and Business Intelligence. Studies in Classification, Data Analysis, and Knowledge Organization.

Béatrice REY

Current position: *Maître de Conférences* (Associate Professor), University of Lyon, University Lyon 1 LSAF (Laboratoire de Sciences Actuarielle et Financière) researcher.

E-mail: beatrice.rey-fournier@univ-lyon1.fr

Professional experience, qualifications:

- 2010 H.D.R. in economics, University Lyon 1.
- 1994 Ph. D. in economics, University Toulouse 1.
- 1991 Postgraduate degree in economic and econometrics, University Toulouse 1.

Research interests: Risk Theory, Health Economics, Insurance

Publications and working papers:

1. “Benchmark values for higher coefficients of relative risk aversion”, Michel Denuit and Béatrice Rey, *Theory and Decision*, to appear
2. “On Relative and Partial Risk Attitudes: Theory and Implications”, W.H. Chiu, Louis Eeckhoudt and Béatrice Rey, *Economic Theory*, 2012, 50 : 151-167
3. “Priority setting in health care and higher order degree change in risk”, Christophe Courbage and Béatrice Rey, *Journal of Health Economics*, 2012, 31 : 484-489
4. “Optimal prevention and other risks in a two-period model”, Christophe Courbage

and Béatrice Rey, *Mathematical Social Sciences*, 2012, 63 : 213-217
5. "Prevention and Precaution", Christophe Courbage, Béatrice Rey and Nicolas Treich, chapter book in *Handbook of Insurance*, Kluwer Publishers, 2012
6. "Risk vulnerability: a graphical interpretation", Louis Eeckhoudt et Béatrice Rey, *Theory and Decision*, 2011, 71: 227-234
7. "Preserving preference rankings under non-financial background risk", Yannick Malevergne and Béatrice Rey, *Journal of the Operational Research Society*, 2010, 61 : 1302-1308
8. "Prudence, Temperance, Edginess, and Risk Apportionment as Decreasing Sensitivity to Detrimental Changes", Michel Denuit and Béatrice Rey, *Mathematical Social Sciences*, 2010, 60 : 137-143
9. "Some consequences of correlation aversion in decision science", Michel Denuit, Louis Eeckhoudt and Béatrice Rey, *Annals of Operations Research*, 2010, 176 : 259-269
10. "On Cross Risk Vulnerability", Yannick Malevergne and Béatrice Rey, *Insurance: Mathematics and Economics*, 2009, 45 : 224-229

Christian Yann ROBERT

Age, situation: 37 years, male, married, two children

Current position: *Professeur des Universités* (Full Professor) at Université Lyon 1 since November 2010, Laboratoire de Sciences Actuarielle et Financière (équipe d'accueil 2429)

E-mail: `christian.robert@univ-lyon1.fr` **Web:** `http://isfa.univ-lyon1.fr/christian_robert`

Professional experience, qualifications:

2006–2010	Associate Professor at ENSAE, Paris
2003–2006	Assistant Professor at CNAM, Paris
2002–2003	Actuary at SCOR, Paris
2001–2002	Assistant Professor at ENSAE, Paris
1998–2001	Ph.D. in applied mathematics at University Paris Diderot
1997–1998	Postgraduate degree in Statistics from University Paris Diderot
1995–1998	Postgraduate degree in Statistics and Economics at ENSAE, Paris. Actuary, Member of the Institut des Actuaires

Research interests: Extreme Value Theory and Statistics, Actuarial Theory and Practice, Statistical Finance.

PhD students: 4 PhD supervised students.

Publications and working papers:

1. Robert, C. (2007). Stochastic stability of some state-dependent growth-collapse processes. *Advances in Applied Probability*, 39, 1-32.
2. Robert, C. (2008). Estimating the multivariate extremal index function. *Bernoulli*, 14, 1027-1064.
3. Robert, C. and Segers, J. (2008). Tails of random sums of a heavy-tailed number of light-tailed terms. *Insurance: Mathematics and Economics*, 43, 85-92.
4. Robert, C. (2009). Inference for the limiting cluster size distribution of extreme values. *The Annals of Statistics*, 37, 271-310.
5. Lescourret, L. and Robert, C. (2011). Transparency matters: Price formation in presence of order preferencing. *Journal of Financial Markets*, 14, 227-258.
6. Robert, C. and Rosenbaum, M. (2011). A new approach for the dynamics of ultra high frequency data: the model with uncertainty zones. *Journal of Financial Econometrics*, 9, 344-366.
7. Robert, C. and Rosenbaum, M. (2012). Volatility estimation under endogenous microstructure noise. *Mathematical Finance*, 22, 133-164.

Mathieu ROSENBAUM

Age, situation: 31 years, male, married

Current position: Professor at University Pierre et Marie Curie since September 2011, Laboratory of Probability and Random Models.

E-mail: `mathieu.rosenbaum@polytechnique.edu`

Professional experience, qualifications:

2010 Habilitation à diriger les recherches
2004–2007 PhD Thesis in Financial Statistics, University Paris Est
2003–2004 DEA in Statistics and Random Models, University Paris 7
2001–2004 ENSAE

Research interests: Statistics of Random Processes, Mathematical Finance, Microstructure of Financial Markets.

Editorial responsibilities: Associate Editor of Electronic Journal of Statistics.

Awards: Scor Price 2008

PhD students: 4 PhD students.

Publications and working papers:

1. M. Rosenbaum *Integrated volatility and round off error*, Bernoulli, 15 pp 687-720, 2009.
2. M. Rosenbaum and P. Tankov *Asymptotic results for time-changed Lévy processes sampled at hitting times*, Stochastic Processes and Their Applications, 121 pp 1607-1632, 2011.
3. C.Y. Robert and M. Rosenbaum *A new approach for the dynamics of ultra high frequency data: the model with uncertainty zones*, Journal of Financial Econometrics, 9 pp 344-366, 2011.
4. C.Y. Robert and M. Rosenbaum *Volatility and covariation estimation when microstructure noise and trading times are endogenous*, Mathematical Finance, 15 pp 687-720, 2012.
5. M. Hoffmann, M. Rosenbaum and N. Yoshida *Estimation of the lead-lag parameter from non-synchronous data*, to appear in Bernoulli, 2011.

Didier RULLIÈRE

Age, situation: 39 years, male, civil union, two children

Current position: *Maître de Conférences* (Associate Professor) at Université Lyon 1 since September 2000, Laboratoire de Sciences Actuarielle et Financière (équipe d'accueil 2429). Status of "membre Agrégé" of the French Institute of Actuaries.

E-mail: `didier.rulliere@univ-lyon1.fr`

Professional experience, qualifications:

2000 PhD Thesis, in management sciences.
2000 Consultant actuary at Actuaris company, Lyon.
1996–2000 Actuary at Ecureuil Vie Company, Paris.
1996 Actuarial Diploma, Institut de Science Financière et d'assurances, Lyon 1.

Research interests: Risk theory, default risk models,contagion models, distortions of risk measures, global optimization, kriging.

Coordination of research programs:

Editorial responsibilities:

PhD students: 1 PhD co-supervised student.

Publications and working papers:

1. Rullière, D., Faleh, A., Planchet, F., Youssef, W. (2013) *Exploring or reducing noise ?, a global optimization algorithm in the presence of noise.* to appear in Structural and Multidisciplinary Optimization, doi:10.1007/s00158-012-0874-5
2. Blanchet-Scalliet, C., Dorobantu, D., Rullière, D. (2013) *The density of the ruin time for a renewal-reward process perturbed by a diffusion*, Applied Mathematics Letters, 26, 108-112; doi:10.1016/j.aml.2012.04.003.
3. Bienvenüe, A., Rullière, D. (2012) *Iterative adjustment of survival functions by compositions of probability distortions*, The Geneva Risk and Insurance Review, 37, 156-179; doi:10.1057/grir.2011.7
4. Faleh, A., Planchet, F., Rullière, D. (2010), *Les générateurs de Scénarios Économiques : de la conception à la mesure de la qualité.* Assurances et gestion des risques, Insurance and Risk Man-

agement Journal, Montreal, Vol.78, 1-2.
5. Loisel, S., Mazza, C., Rullière, D. (2009); *Convergence and asymptotic variance of bootstrapped finite-time ruin probabilities with partly shifted risk processes*, Insurance: Mathematics and Economics, vol. 45, 3, pages 374-381.

Yahia SALHI

Age, situation: 28 years, male

Current position: *Maître de Conférences Associé* (Associate Professor) at Université Lyon 1 since September 2012, Laboratoire de Sciences Actuarielle et Financière (équipe d'accueil 2429)

E-mail: yahia.salhi@gmail.com **Web:** http://sites.google.com/site/yahiasalhi/

Professional experience, qualifications:

2009–2012 *A.T.E.R* (Research Assistant) at ISFA, Lyon 1; PhD Thesis, in applied mathematics, Laboratoire de Science Actuarielle et Financière, Université Lyon 1

2009-2012 Research associate on longevity risk in the Chair "Derivatives of the future", sponsored by the French Federation of Banks and chaired by Nicole El Karoui.

2007–2012 *R&D Actuary*, R&D Center on Longevity/Mortality Risk, SCOR Global Life

2007–2008 Master 2 in Financial and Actuarial Sciences, Université Lyon 1

2005–2008 Ecole des Mines de Saint-Etienne, Civil Engineer

Research interests: Longevity Risk, Stochastic Mortality, Mortality Modeling, Basis Risk, Sequential Detection, Survival Analysis, Risk Sharing

Reviewal responsibilities: Reviewed publications in EUAJ, MCAP, BFA

Publications and working papers:

1. Barrieu, P., Bensusan, H., El Karoui, N., Hillairet, C., Loisel, S., Ravanelli, C. and Salhi, Y. *Understanding, modelling and managing longevity risk: key issues and main challenges*, vol. 2012(3) pp. 203–231 (2012)
2. Salhi, Y. and Loisel, S. *Basis risk modelling: a co-integration based approach*, submitted (2011)
3. Bensusan, H., El Karoui, N., Loisel, S. and Salhi, Y. *Partial Splitting of Longevity and Financial Risks: The Longevity Nominal Choosing Swaptions*, submitted (2012)
4. Salhi, Y., Loisel, S. and El Karoui, N. *Practical Use of Change-Point Analysis for Mortality Data*, preprint (2013)
5. Salhi, Y., Loisel, S. and El Karoui, N. *Monitoring Longevity Basis Risk*, preprint (2013)

Julien TOMAS

Age, situation: 33 years, male

Current position: *Postdoc* at Université Lyon 1 since December 2012, Laboratoire de Sciences Actuarielle et Financière in partnership with the Chair Management de la Modélisation and the French Institute of Actuaries

E-mail: drjtomas@gmail.com

Professional experience, qualifications:

2009–2012 Ph.D in Economics and Business - *Economie en Bedrijfskunde* Title : Quantifying biometric life insurance risks with non-parametric methods, Amsterdam School of Economic Research Institute - University of Amsterdam - The Netherlands

2008–2009 R&D on Longevity/Mortality Modelling, Divisional Unit : Financial Solutions Life and Health - MunichRe - Germany

2005–2008 Teaching Assistant in Actuarial sciences, Financial Times Series, Econometrics University of Amsterdam - The Netherlands

2003–2004 Research associate at Laboratory of Applied and Theoretical Economics Delta Ens - Cnrs - Ehess Research Unit Paris-Jourdan Sciences Economiques - Paris - France

2003–2004 Master in Health Economics Faculté de Médecine Paris XI - France

2002–2003 Master in Econometrics, Microeconomics and Industrial Economics Maison des Sciences Economiques - Université Paris 1 Panthéon Sorbonne - France

Research interests: Stochastic mortality modelling, Longevity risk, Long-Term Care insurance, Non-parametric estimation, Multidimensional smoothing, Functional analysis

Publications and working papers:

1. Tomas, J. and Planchet, F. *Prospective mortality tables and portfolio experience*, Chapter 9 in Computational Actuarial Science, with R, Arthur Charpentier Editor, Chapman, preprint (2014)
2. Tomas, J. and Planchet, F. *Constructing entity specific prospective mortality table : adjustment to a reference*, submitted (2013)
3. Planchet, F. and Tomas, J. *Uncertainty on survival probabilities and solvency capital requirement : application to long-term care insurance*, submitted (2013)
4. Tomas, J. and Planchet, F. *Construction d'une table de mortalité par positionnement : Mode d'emploi*, Technical report II1291-15, Institut des Actuaires, pp. 1-29 (2013)
5. Tomas, J. and Planchet, F. *Critères de Validation : Aspects Méthodologiques*, Technical report II1291-14, Institut des Actuaires, pp. 1-31 (2013)
6. Tomas, J. and Planchet, F. *L'Approche Développée par le CMI pour la Construction de Tables Prospectives Spécifiques*, Technical report II1291-13, Institut des Actuaires, pp. 1-9 (2013)
7. Tomas, J. and Planchet, F. *Méthodes de Positionnement : Aspects Méthodologiques*, Technical report II1291-12, Institut des Actuaires, pp. 1-14 (2013)
8. Tomas, J. and Planchet, F. *Construction et Validation des Références de Mortalité de Place*, Technical report II1291-11, Institut des Actuaires, pp. 1-38 (2013)
9. Tomas, J. and Planchet, F. *Multidimensional smoothing by adaptive local kernel-weighted log-likelihood with application to long-term care insurance*, Insurance : Mathematics & Economics, vol. 52(3), pp. 573-589 (2013)
10. Tomas, J *Univariate graduation of mortality by local polynomial regression*, Bulletin Français d'Actuariat, vol. 12(23), pp. 5-58 (2012)
11. Tomas, J *Essays on boundaries effects and practical considerations for graduation of mortality by local likelihood models*, Insurance and Risk Management, vol. 80(2), pp. 203-261 (2012)
12. Tomas, J *A local likelihood approach to univariate graduation of mortality*, Bulletin Français d'Actuariat, vol. 11(22), pp. 105-153 (2011)

Jessica TRESSOU

Age, situation: 34 years, female, married, two children

Current position: *Chargée de recherche* (Permanent researcher) at National Institute for Agronomic Resaerch (INRA) since January 2007, Met@risk : Methodologies for Food Risk Analysis (Unité 1204).

E-mail: Jessica.Tressou@agroparistech.fr

Web: http://paris.inra.fr/metarisk/our_team/tressou_cosmao_jessica

Professional experience, qualifications:

Fall 2011 Instructor at Columbia University, New York, USA

2007–2009 Visiting scholar, Instructor (statistics courses), Hong Kong University of Science and Technology (HKUST)

Fall 2006 Postdoctoral fellow, with Prof. Albert Lo, HKUST

Spring 2006 Program assistant, with Prof. Albert Lo, HKUST

2004–2005 PhD student, INRA Met@risk, Paris, France

2002–2003 PhD student, INRA Corela, Ivry-sur-Seine, France

Research interests: Food Risk Analysis, Extreme value Analysis, Simulation & Resampling Techniques, U-Statistics, Bootstrap, Monte Carlo Markov Chains, Survival Analysis, Markovian Processes & Regeneration, Bayesian Nonparametric Statistics, Statistical Learning.

Awards: ERS IASC Young Researchers Award, COMPSTAT, Prague, 2004.

Publications and working papers:

1. P. Bertail, S. Clémençon & J. Tressou *Regenerative Block-Bootstrap Confidence Intervals for Tails and Extremal Indexes* Submitted, 2012.
2. Bertail, P., S. Clémençon & J. Tressou *Statistical analysis of a dynamic model for food contaminant exposure with applications to dietary methylmercury contamination* Journal of Biological Dynamics 4(2), 212-234, 2010.
3. Bertail, P., S. Clémençon & J. Tressou *Extreme value statistics for Markov chains via the (pseudo-)regenerative method* Extremes 12(4), 327-360, 2009.
4. Bertail, P., S. Clémençon, S. & Tressou, J. *A Storage Model With Random Release Rate For Modeling Exposure To Food Contaminants* Mathematical Biosciences and Engineering 5(1), 35-60, 2008.
5. Tressou, J. *Bayesian Nonparametrics for Heavy Tailed Distribution. Application to Food Risk Assessment* Bayesian Analysis 3(2), 367-392, 2008.

Julien VEDANI

Age, situation: 25 years, male, single

Current position: PhD Student at Université Lyon 1 since March 2012, Laboratoire de Sciences Actuarielle et Financière.

E-mail: `julien.vedani@etu.univ-lyon1.fr`

Professional experience, qualifications:

2010–2012 Institut d'Etudes Politiques de Paris, Master 2 in Finance and Strategy

2010–2011 Actuarial Diploma, Ecole Nationale de la Statistique et de l'Administration Economique de Malakoff

2007–2011 Ecole Nationale de la Statistique et de l'Administration Economique de Malakoff, Master's degree in Statistical and Economical Engineering

Research interests: The Own Risk and Solvency Assessment implementation, Monitoring solvency through years, Multi-year Nested Simulations and its alternatives, Order statistics.

Publications and working papers:

1. J. Vedani, L. Devineaul *Solvency assessment within the ORSA framework: issues and quantitative methodologies*, submited
2. J. Vedani, S. Loisel *Use of Net Present Value of margins to approximate the Net Asset Value adversity order*, in progress
3. J. Vedani, L. Devineau *Permanent conformity within the ORSA framework* , in progress

6 Justification scientifique des moyens demandés / Scientific justification of requested ressources

Our requested budget consisted in:

- Personal costs : 1 twelve month post-doctoral student to be hired, 1 twenty-four-month *Ingénieur de recherche* to be hired, 1 three years PhD student to be hired. With these positions, the project will also contribute to the training of young researchers in the field of probability and statistics applied to insurance. There is an important lack of young researchers in these field in France whereas the demand of highly trained mathematicians is very important both in the academic world and in the insurance business. The post-doctoral student will be supervised by Christian Robert and mainly work on Task 2. The PhD student will be supervised by the coordinator, with a co-supervisor at Partner 2. The PhD student will work on Tasks 1, 3 and 5 (longevity models and simulation issues, as well as fast detection problems). The *Ingénieur de recherche* will mainly work on Task 3, under the supervision of Gilles Pagès. His/her role will also be important for Tasks 1 and 5.
- Cost for internal meetings: we shall organize 2 internal thematic meetings each year. These meetings will be organized successively by each partner. These meeting will gather all the project members during two days. Each meeting will have two components: parallel small meetings on precise points of the project and a large meeting where the results of the project will be reported.
- Cost for informal meeting between members of the project, that correspond for instance to one task of the present proposal.
- Organization of one workshop and one international conference. This will give an international visibility to the project and will be the occasion to present the results of the project to the international community, as well as developing new collaborations.
- International researchers invitations. We would like to invite foreign researchers in order to reinforce existing collaborations or to develop new ones, according to the consistency of the project.
- Participation to international conferences and workshops
- One massively parallel computing device
- Small computing material. We shall buy computers for the PhD student, the *ingénieur de recherche* and the post-doctoral student.
- Acquisition of books to facilitate inter-disciplinary applications.

The total requested budget is 562 328 euros (including management fees (21628 euros) and tax).

6.1 Équipement / Equipment

Initial needs
Roughly speaking, the modeling of longevity among a human population can be developed either from deterministic (and macroscopic) or stochastic (and microscopic) point of view. The main asset of the second approach is to observe the emergence of rare events. Such phenomenons turn out to be crucial when dealing with longevity risks associated to long run financial products like variable annuities and their variants. As expected, the simulation of large populations characterized by many traits is very demanding. One aspect of our project in terms of numerical simulation is to implement implement on massively parallel computing device (typically GPU Calculator including NVIDIA cards to implement the models in CUDA). GPGPU techniques are already used in our laboratory (essentially to compute primal and dual optimal quantization grids) but never at the scale needed to model population dynamics. Researchers at LPMA have the expertise to program in such an environment. The challenging aspects from a numerical probability aspects is to adapt the underlying interacting particles methods used in population dynamics to take full advantage of the parallelization. To be more precise we need the following architecture: GPU cards = 4 x 2700 euros HT = 10 800 euros HT, a server = 5500 euros HT, which makes a global budget of 16300 Euros HT, approx. 18300 including tax (for partner 2). This device will be devoted to the simulation of the evolution of large population over a long period of time (say 10, 20 or 30 years) with various demographic and economic scenarios. It will be a benchmark for testing new variance reduction methods (importance sampling for particle methods, stratification, etc) and other techniques devised to speed up the simulations of the population as well as the computations of some companion quantities like the price and the risks

induced by new mixed insurance/financial products.
We will also need light hardware equipment for the three non-permanent positions: $3x2000 = 6000$ euros (2 for Partner 1, and 1 for Partner 2).

Revised needs:
The hardware is going to be funded by other sources. We just need light hardware equipment for the post-doc position: 2000 euros.
New Total for equipment: 2 000 euros (decomposed into 2000 euros for Partner 1 and 0 euros for Partner 2) .

6.2 Personnel / Staff

- 1 Post-Doc position (2 years, to be hired during the 1st or 2nd year of the project): 100000 euros (Partner 1)

Total for staff: 100 000 euros (100000 for Partner 1, 0 for Partner 2).
Note that one PhD grant has been obtained by Partner 2 with other funding.

6.3 Prestation de service externe / Subcontracting

Lyon Ingénierie Projets will be in charge of

- the administrative and financial management of the project,
- the Intellectual Property Rights (if necessary),
- the support for the project dissemination.

Cost for these services for the 4 years of the project and the 2 partners is 3000 euros (Partner 1).

6.4 Missions / Travel

Since the 29 participants are spread in several laboratories, this corresponds to a quite large number of trips, but it is justified since the success of this project mainly relies on the ability to have deep collaborations.

- *Organization of 8 full internal meetings (2 per year)*. We shall cover all the fees of the participants, average cost is 200 euros per person and per 2-day meeting. 46400 euros ($= 200 * 8 * 29$). (decomposed into $18/29$ for Partner 1 and $11/29$ for Partner 2)
- *Support for informal workshops between the participants of the project*. Average cost is 200 euros per person, for a 2-day meeting. We shall support 2 meetings of this kind per year and for each participant. 46400 euros ($= 200 * 8 * 29$). (decomposed into $18/29$ for Partner 1 and $11/29$ for Partner 2)
- We shall support the participants of the project for their participation to international conferences according to the consistency with the project (conferences on probability and statistics, dynamic population models, actuarial science, simulation methods, ...). This is important for the project members to inform the different communities of their results and to keep interactions with other communities. Average cost is 2000 euros per person and per conference. 2 conferences in average per person. 116000 euros ($= 2000 * 29 * 2$). (decomposed into $18/29$ for Partner 1 and $11/29$ for Partner 2)
- organization of 1 workshop during the 1st year: 15000 euros (by Partner 1)
- organization of 1 international conference in the last year to disseminate results: 15000 euros (by Partner 2)
- invitations of 8 researchers from abroad (stays from 1 week to 1 month): 2000x$8 = 16000$ euros. (5 by Partner 1 and 3 by Partner 2)

Old total for missions: 254 800 euros.

This total for missions has been rescaled in order to fit the amount granted by the ANR. The new total for missions is 170 846 euros. Besides, Partner 1 represents 18/29 of the staff in terms of persons, and 475/900 in terms of persons weighted by time allocated to the project. We finally choose a compromise between the two approaches and consider that Partner 1 represents around 57%. So the new total for missions (170 846 euros) is decomposed into 98106 euros for Partner 1 and 72740 for Partner 2.

6.5 Autres dépenses de fonctionnement / Other expenses

We plan to buy a total of 30 books throughout the project: $30\text{x}100 = 3000$ euros. Here is the breakdown of the expenses : 1600 euros for Partner 1 and 1400 euros for Partner 2.

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