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ASTIN Bulletin

46(1), 2016

AASE, KNUT K. *Life insurance and pension contracts II: the life cycle model with recursive utility.* 71-102. We analyze optimal consumption and pension insurance during the life time of a consumer using the life cycle model, when the consumer has recursive utility. The relationship between substitution of consumption and risk aversion is highlighted, and clarified by the introduction of this type of preferences. We illustrate how recursive utility can be used to explain the empirical consumption puzzle for aggregates. This indicates a plausible choice for the parameters of the utility function, relevant for the consumer in the life cycle model. Optimal life insurance is considered, as well as the portfolio choice problem related to optimal exposures in risky securities. A major finding is that it is optimal for the typical insurance buyer to smooth adverse shocks to the financial market, unlike what is implied by the conventional model. This has implications for what type of contracts the life and pension insurance industry should offer.

ARNOLD-GAILLE, SÉVERINE; SHERRIS, MICHAEL. *International cause-specific mortality rates: new insights from a cointegration analysis.* 9-38. This paper applies cointegration techniques, developed in econometrics to model long-run relationships, to cause-of-death data. We analyze the five main causes of death across five major countries, including USA, Japan, France, England & Wales and Australia. Our analysis provides a better understanding of the long-run equilibrium relationships between the five main causes of death, providing new insights into similarities and differences in trends. The results identify for the first time similarities between countries and genders that are consistent with past studies on the aging processes by biologists and demographers. The insights from biological theory on aging are found to be reflected in the cointegrating relations in all of the countries included in the study.

CHEN, XINXIANG; CHI, YICHUN; TAN, KEN SENG. *The design of an optimal retrospective rating plan.* 141-163. A retrospective rating plan, whose insurance premium depends upon an insured's actual loss during the policy period, is a special insurance agreement widely used in liability insurance. In this paper, the design of an optimal retrospective rating plan is analyzed from the perspective of the insured who seeks to minimize its risk exposure in the sense of convex order. In order to reduce the moral hazard, we assume that both the insured and the insurer are obligated to pay more for a larger realization of the loss. Under the further assumptions that the minimum premium is zero, the maximum premium is proportional to the expected indemnity, and the basic premium is the only free parameter in the formula for retrospective premium given

by Meyers (2004) [Meyers, G.G. (2004), Retrospective premium, in J. Teugels and B. Sundt (eds.) (2004), *Encyclopedia of Actuarial Science*, volume 3, p. 1452-1456] and that the basic premium is determined in such a way that the expected retrospective premium equates to the expected indemnity with a positive safety loading, we formally establish the relationship that the insured will suffer more risk for a larger loss conversion factor or a higher maximum premium. These findings suggest that the insured prefers an insurance policy with the expected value premium principle, which is a special retrospective premium principle with zero loss conversion factor. In addition, we show that any admissible retrospective rating plan is dominated by a stop-loss insurance policy. Finally, the optimal retention of a stop-loss insurance is derived numerically under the criterion of minimizing the risk-adjusted value of the insured's liability where the liability valuation is carried out using the cost-of-capital approach based on the conditional value at risk.

CHULIÁ, HELENA; GUILLÉN, MONTSERRAT; URIBE, JORGE M. *Modeling longevity risk with generalized dynamic factor models and vine-copulae*. 165-190. We present a methodology to forecast mortality rates and estimate longevity and mortality risks. The methodology uses generalized dynamic factor models fitted to the differences in the log-mortality rates. We compare their prediction performance with that of models previously described in the literature, including the traditional static factor model fitted to log-mortality rates. We also construct risk measures using vine-copula simulations, which take into account the dependence between the idiosyncratic components of the mortality rates. The methodology is applied to forecast mortality rates for a population portfolio for the UK and to estimate longevity and mortality risks.

LEMAIRE, JEAN; PARK, SOJUNG CAROL; WANG, KILI C. *The use of annual mileage as a rating variable*. 39-69. Auto insurance companies must adapt to ever-evolving regulations and technological progress. Several variables commonly used to predict accidents rates, such as gender and territory, are being questioned by regulators. Insurers are pressured to find new variables that predict accidents more accurately and are socially acceptable. Annual mileage seems an ideal candidate. The recent development in new technologies should induce insurance carriers to explore ways to introduce mileage-based insurance premiums. We use the unique database of a major insurer in Taiwan to investigate whether annual mileage should be introduced as a rating variable in auto third-party liability insurance. We find that annual mileage is an extremely powerful predictor of the number of claims at-fault. The inclusion of mileage as a new variable should, however, not take place at the expense of bonus-malus systems; rather, the information contained in the bonus-malus premium level complements the value of annual mileage. An accurate rating system should therefore include annual mileage and bonus-malus as the two main building blocks, possibly supplemented by the use of other variables like age, territory and engine cubic capacity. While Taiwan has specific characteristics (high traffic density, a mild bonus-malus system and limited compulsory auto coverage), our results are so strong that we can confidently conjecture that they extend to all developed nations.

THOMSON, ROBERT; SAHIN, SULE; REDDY, TARYN. *How a single-factor CAPM works in a multi-currency world*. 103-139. In this paper, a single-factor multi-currency (SFM) capital-asset pricing model (SFM-CAPM) is developed. The advantage in using a single-factor model is that it does not treat currency risks as carrying different weight from investment risks; regardless of its source, risk is measured as variance, and weighted accordingly. The aim of this paper is primarily to give actuaries a way ahead in the use of the single-factor CAPM in a multi-currency world for the purposes of the stochastic modelling of the assets and liabilities of long-term financial institutions, such as pension funds, particularly for the purposes of liability-driven investments

and market-consistent valuation, and the application of the model has been designed with that intention. However, it is envisaged that the model will also be of interest to other practitioners. The paper's major original contribution to the literature is its proof that, for a single-factor CAPM to work in a multi-currency world, there is a necessary condition. The theory is applied to two major currencies and two minor currencies, namely the US dollar, the UK pound, the South African rand and the Turkish lira.

TSANAKAS, ANDREAS; BECK, MICHAEL BRUCE; THOMPSON, MICHAEL. *Taming uncertainty: the limits to quantification*. 1-7. Taming the beast of uncertainty has been the grand project to which actuaries have dedicated much of their energy and skill over at least the last 50 years – roughly the time since, in Hans Bühlmann's (1989) famous term, "Actuaries of the Second Kind" emerged.

ASTIN Bulletin

46(2), 2016

AFONSO, LOURDES B; CORTE-REAL, PEDRO. *Using weighted distributions to model operational risk*. 469-485. The quantification of operational risk has to deal with various concerns regarding data, much more than other types of risk which banks and insurers are obliged to manage. One of the main questions that worries both researchers and practitioners is the bias in the data on the operational losses amounts recorded. We support the assertions made by several authors and defend that this concern is serious when modeling operational losses data and, typically, is presented in all the databases. We show that it's possible, based on mild assumptions on the internal procedures put in place to manage operational losses, to make parametric inference using loss data statistics, that is, to estimate the parameters for the losses amounts, taking in consideration the bias that, not being considered, generates a two fold error in the estimators for the mean loss amount and the total loss amount, the former being overvalued and the last undervalued. In this paper, we do not consider the existence of a threshold for which, all losses above, are reported and available for analysis and estimation procedures. In this sense, we follow a different approach to the parametric inference. Here, we consider that the probability that a loss is reported and ends up recorded for analysis, increases with the size of the loss, what causes the bias in the database but, at the same time, we do not consider the existence of a threshold, above which, all losses are recorded. Hence, no loss has probability one of being recorded, in what we defend is a realist framework. We deduce the general formulae, present simulations for common theoretical distributions used to model (operational reported) losses amounts, estimate the impact for not considering the bias factor when estimating the value at risk and estimate the true total operational losses the bank incurred.

BOONEN, TIM J; TAN, KEN SENG; ZHUANG, SHENG CHAO. *Pricing in reinsurance bargaining with comonotonic additive utility functions*. 507-530. Optimal reinsurance indemnities have widely been studied in the literature, yet the bargaining for optimal prices has remained relatively unexplored. Therefore, the key objective of this paper is to analyze the price of reinsurance contracts. We use a novel way to model the bargaining powers of the insurer and reinsurer, which allows us to generalize the contracts according to the Nash bargaining solution, indifference pricing and the equilibrium contracts. We illustrate these pricing functions by means of inverse-S shaped distortion functions for the insurer and the Value-at-Risk for the reinsurer.

BOUCHER, JEAN-PHILIPPE; COUTURE-PICHÉ, GUILLAUME. *Modeling the number of insured households in an insurance portfolio using queuing theory*. 401-430. In this paper, we use queuing theory to model the number of insured households in an insurance portfolio. The model is based on an idea from Boucher and Couture-Piché (2015) [Boucher, J.-P. and Couture-Piché, G. (2015) Modeling the number of insureds' cars using queuing theory. *Insurance: Mathematics and Economics*, 64, 67-76], who use a queuing theory model to estimate the number of insured cars on an insurance contract. Similarly, the proposed model includes households already insured, but the modeling approach is modified to include new households that could be added to the portfolio. For each household, we also use the queuing theory model to estimate the number of insured cars. We analyze an insurance portfolio from a Canadian insurance company to support this discussion. Statistical inference techniques serve to estimate each parameter of the model, even in cases where some explanatory variables are included in each of these parameters. We show that the proposed model offers a reasonable approximation of what is observed, but we also highlight the situations where the model should be improved. By assuming that the insurance company makes a \$1 profit for each one-year car exposure, the proposed approach allows us to determine a global value of the insurance portfolio of an insurer based on the customer equity concept.

HAO, MINGJIE; MACDONALD, ANGUS S; TAPADAR, PRADIP; THOMAS, R GUY. *Insurance loss coverage under restricted risk classification: the case of iso-elastic demand*. 265-291. This paper investigates equilibrium in an insurance market where risk classification is restricted. Insurance demand is characterised by an iso-elastic function with a single elasticity parameter. We characterise the equilibrium by three quantities: equilibrium premium; level of adverse selection (in the economist's sense); and "loss coverage", defined as the expected population losses compensated by insurance. We consider both equal elasticities for high and low risk-groups, and then different elasticities. In the equal elasticities case, adverse selection is always higher under pooling than under risk-differentiated premiums, while loss coverage first increases and then decreases with demand elasticity. We argue that loss coverage represents the efficacy of insurance for the whole population; and therefore that if demand elasticity is sufficiently low, adverse selection is not always a bad thing.

JOSHI, MARK S; ZHU, DAN. *The efficient computation and the sensitivity analysis of finite-time ruin probabilities and the estimation of risk-based regulatory capital*. 431-467. Solvency regulations require financial institutions to hold initial capital so that ruin is a rare event. An important practical problem is to estimate the regulatory capital so the ruin probability is at the regulatory level, typically with less than 0.1% over a finite-time horizon. Estimating probabilities of rare events is challenging, since naive estimations via direct simulations of the surplus process is not feasible. In this paper, we present a stratified sampling algorithm for estimating finite-time ruin probabilities. We further introduce a sequence of measure changes to remove the pathwise discontinuities of the estimator, and compute unbiased first and second-order derivative estimates of the finite-time ruin probabilities with respect to both distributional and structural parameters. We then estimate the regulatory capital and its sensitivities. These estimates provide information to insurance companies for meeting prudential regulations as well as designing risk management strategies. Numerical examples are presented for the classical model, the Sparre Andersen model with interest and the periodic risk model with interest to demonstrate the speed and efficacy of our methodology.

PLA-PORCEL, JAVIER; VENTURA-MARCO, MANUEL; VIDAL-MELIÁ, CARLOS. *Life care annuities (LCA) embedded in a notional defined contribution (NDC) framework*. 331-363.

This paper examines the possibility of embedding public long-term care (LTC) insurance within the retirement pension system, i.e. introducing life care annuities into a notional defined contribution framework. To do this, we develop a multistate overlapping generations model that includes the so-called survivor dividend and give special attention to the assumptions made about mortality rates for dependent persons and LTC incidence rates, which largely determine the contribution rate assigned to LTC. The proposed model could be of interest to policymakers because it could be implemented without too much difficulty, it would universalize LTC coverage with a “fixed” cost, and it would discourage politicians from making promises about future LTC benefits without the necessary funding support.

RÖHR, ANCUS. *Chain ladder and error propagation*. 293-330. We show how estimators for the chain ladder prediction error in Mack’s (1993) distribution-free stochastic model [Mack, T. (1993) Distribution-free calculation of the standard error of chain ladder reserve estimates. *ASTIN Bulletin* (1993) 23(2): 213-225] can be derived using the error propagation formula. Our method allows for the treatment of the general case of the prediction error of the loss development result between two arbitrary future horizons. In the well-known special cases considered previously by Mack (1993) and Merz and Wüthrich (2008), our estimators coincide with theirs. However, the algebraic form in which we cast them is new, considerably more compact and more intuitive to understand. For example, in the classical case treated by Mack (1993), we show that the mean squared prediction error divided by the squared estimated ultimate loss can be written as $\sum_j \hat{u}_j^2 \hat{q}_j$, where \hat{u}_j measures the (relative) uncertainty around the j th development factor and \hat{q}_j the proportion of the estimated ultimate loss that it affects. The error propagation method also provides a natural split into process error and parameter error. Our proofs identify and exploit symmetries of “chain ladder processes” in a novel way. For the sake of wider practical applicability of the formulae derived, we allow for incomplete historical data and the exclusion of outliers in the triangles.

TAYLOR, GREG; WONG, BERNARD. *Correlations between insurance lines of business: an illusion or a real phenomenon? Some methodological considerations*. 225-263. This paper is concerned with dependency between business segments in the non-life insurance industry. When considering the business of an insurance company at the aggregate level, dependence structures can have a major impact in several areas of Enterprise Risk Management, such as in claims reserving and capital modelling. The accurate estimation of the diversification benefits related to the dependence structures between lines of business (LoBs) is crucial for (i) capital efficiency, as one should avoid holding unnecessarily high levels of capital, and (ii) solvency of the insurance company, as an underestimation, on the other hand, may lead to insufficient capitalisation and safety. There seems to be a great deal of preconception as to how dependent insurance claims should be. Often, presence of dependence is taken as a given and rarely discussed or challenged, perhaps because of the lack of extensive datasets to be publicly analysed. In this paper, we take a different approach, and consider how much correlation some real datasets actually display (the Meyers-Shi dataset from the USA, and the AUSI dataset from Australia). We develop a simple theoretical framework that enables us to explain how and why correlations can be illusory (and what we mean by that). We show with some real examples that, sometimes, most (if not all) of the correlation can be “explained” by an appropriate methodology. Two major conclusions stem from our analysis.

TEICHMANN, JOSEF; WÜTHRICH, MARIO V. *Consistent yield curve prediction*. 191-224. We present an arbitrage-free non-parametric yield curve prediction model which takes the full

discretized yield curve data as input state variable. Absence of arbitrage is a particularly important model feature for prediction models in case of highly correlated data as, for instance, interest rates. Furthermore, the model structure allows to separate constructing the daily yield curve from estimating its volatility structure and from calibrating the market prices of risk. The empirical part includes tests on modeling assumptions, out-of-sample back-testing and a comparison with the Vasicek (1977) short-rate model [Vasicek, O (1977) An equilibrium characterization of the term structure, *Journal of Financial Economics* (1977) 5(2): 177-188].

WANG, HSIN CHUNG; YUE, JACK C; TSAI, YI-HSUAN. *Marital status as a risk factor in life insurance: an empirical study in Taiwan*. 487-505. Gender and age are the top two risk factors considered in pricing life insurance products. Although it is believed that mortality rates are also related to other factors (e.g. smoking, overweight, and especially marriage), data availability and marketing often limit the possibility of including them. Many studies have shown that married people (particularly men) benefit from the marriage, and generally have lower mortality rates than unmarried people. However, most of these studies used data from a population sample; their results might not apply to the whole population. In this study, we explore if mortality rates differ by marital status using mortality data (1975-2011) from the Taiwan Ministry of the Interior. In order to deal with the problem of small sample sizes in some marital status groups, we use graduation methods to reduce fluctuations in mortality rates. We also use a relational approach to model mortality rates by marital status, and then compare the proposed model with some popular stochastic mortality models. Based on computer simulation, we find that the proposed smoothing methods can reduce fluctuations in mortality estimates between ages, and the relational mortality model has smaller errors in predicting mortality rates by marital status. Analyses of the mortality data from Taiwan show that mortality rates differ significantly by marital status. In some age groups, the differences in mortality rates are larger between marital status groups than between smokers and non-smokers. For the issue of practical consideration, we suggest modifications to include marital status in pricing of life insurance products.

YAO, DINGJUN; YANG, HAILIANG; WANG, RONGMING. *Optimal dividend and reinsurance strategies with financing and liquidation value*. 365-399. This study investigates a combined optimal financing, reinsurance and dividend distribution problem for a big insurance portfolio. A manager can control the surplus by buying proportional reinsurance, paying dividends and raising money dynamically. The transaction costs and liquidation values at bankruptcy are included in the risk model. Under the objective of maximising the insurance company's value, we identify the insurer's joint optimal strategies using stochastic control methods. The results reveal that managers should consider financing if and only if the terminal value and the transaction costs are not too high, less reinsurance is bought when the surplus increases or dividends are always distributed using the barrier strategy.

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European Actuarial Journal

6(1), 2016

ARBENZ, PHILIPP; GUEVARA-ALARCÓN, WILLIAM. *Risk measure preserving piecewise linear approximation of empirical distributions*. 113-148. Stochastic models used for pricing, reserving, or capital modelling in insurance companies are often very complex, which is why resulting distributions are typically approximated by Monte Carlo simulations. Both the market and regulators exert increasing pressure not to discard the resulting sample distributions, but rather to store them for future review, audit, or validation, as well as to transfer them between actuarial systems. The present work introduces a compression algorithm which approximates an empirical univariate distribution function through a piecewise linear distribution. In contrast to keeping the full sample, such an approximation facilitates the storage and data transfer of the results by drastically reducing memory requirements. The approximation algorithm preserves the mean and imposes a uniformly bounded relative error over a space of coherent risk measures (TVaR). An efficient, open source implementation is provided.

BERGEL, AGNIESZKA I; EGÍDIO DOS REIS, ALFREDO D. *Ruin problems in the generalized Erlang(n) risk model*. 257-275. For actuarial applications we consider the Sparre-Andersen risk model when the interclaim times are Generalized Erlang(n) distributed. Unlike the standard Erlang(n) case, the roots of the generalized Lundberg's equation with positive real parts can be multiple. This has a significant impact in the formulae for ruin probabilities that have to be found. We start by addressing the problem of solving an integro-differential equation that is satisfied by the survival probability, as well as other probabilities related, and present a method to solve such equation. This is done by considering the roots with positive real parts of the generalized Lundberg's equation, and then establishing a one-one relation between them and the solutions of the integro-differential equation mentioned above. We first study the cases when all the roots are single and when there are roots with higher multiplicity. Secondly, we show that it is possible to have double roots but no higher multiplicity. Also, we show that the number of double roots depend on the choice of the parameters of the generalized Erlang(n) distribution, with a maximum number depending on n being even or odd. Afterwards, we extend our findings above for the computation of the distribution of the maximum severity of ruin as well as, considering an interest force, to the study the expected discounted future dividends, prior to ruin. Our findings show an alternative and more general method to the one provided by Albrecher et al. [Albrecher H., Claramunt M.M., Mármol M. (2005), On the distribution of dividend payments in a Sparre Andersen model with generalized Erlang(n) interclaim times. *Insurance: Mathematics and Economics* (2005) 37: 324-334], by considering a general claim amount distribution.

HUBER, JOEL; WÜTHRICH, MARIO V. *Case study of Swiss mortality using Bayesian modeling*. 25-59. Most mortality models to date in life insurance have inconsistent modeling assumptions

between past and future survival probabilities. This paper aims at correcting this inconsistency by introducing a Bayesian framework for the joint modeling of past survival probabilities and the forecasting of future survival probabilities. To that end, the Bayesian modeling framework introduced considers both the uncertainty in the populations counts (random effects) as well as the uncertainty in the survival probability surface (systemic effects). In particular, the model uses an n -dimensional latent risk factor process to encode the survival probability surface, taking into account its intrinsic dependencies. We use the model for a case study of Swiss mortality. The case study shows that the model fits well to Swiss data and systemic events in the Swiss survival probability surface are captured by the model. The Swiss case study also exhibits the different rate of improvements in mortality for different age groups of the Swiss population.

KRAYZLER, MIKHAIL; ZAGST, RUDI; BRUNNER, BERNHARD. *Closed-form solutions for Guaranteed Minimum Accumulation and Death Benefits*. 197-231. Guaranteed Minimum Accumulation and Death Benefits (GMAB and GMDB) are two common types of variable annuity (VA) products providing participation at the financial markets and the guarantees at the same time. At maturity for a GMAB or at the time of death for a GMDB, these contracts offer the maximum of VA account and some guaranteed benefit. This paper considers four of the most popular options for this guaranteed amount: capital protection, minimum interest return, ratchet and the maximum of them. As these products are exposed to different risk factors, a multi-factor model is required. However, there is often a tradeoff between a realistic model and analytical tractability. Thus, some authors simplify the modeling framework to derive closed-form solutions, others use different numerical methods to price the guarantees. This work aims to fill this gap by providing analytical formulas for Guaranteed Minimum Accumulation and Death Benefits with common riders in a hybrid model for actuarial and financial risks. Incorporation of independent surrenders is discussed.

MAUME-DESCHAMPS, VÉRONIQUE; RULLIÈRE, DIDIER; SAID, FARAH. *On a capital allocation by minimization of some risk indicators*. 177-196. European insurance sector will soon be faced with the application of the Solvency 2 regulation norms. It will create a real change in the risk management of insurance practices. The ORSA (Own Risk and Solvency Assessment) approach of the second pillar makes the capital allocation an important exercise for all insurers, especially when it comes to groups. Considering multi-branches firms, a capital allocation has to be based on multivariate risk modeling. Several allocation methods are present in the actuarial literature and insurance practices. In this paper, we focus on a risk allocation method. By minimizing some of the multivariate risk indicators, we study the coherence of the risk allocation using an axiomatic approach. Furthermore, we discuss what can be the best allocation choice for an insurance group.

RATOVOMIRIJA, GILDAS. *On mixed Erlang reinsurance risk: aggregation, capital allocation and default risk*. 149-175. In this paper, we address the aggregation of dependent stop loss reinsurance risks where the dependence among the ceding insurer(s) risks is governed by the Sarmanov distribution and each individual risk belongs to the class of Erlang mixtures. We investigate the effects of the ceding insurer(s) risk dependencies on the reinsurer risk profile by deriving a closed formula for the distribution function of the aggregated stop loss reinsurance risk. Furthermore, diversification effects from aggregating reinsurance risks are examined by deriving a closed expression for the risk capital needed for the whole portfolio of the reinsurer and also the allocated risk capital for each business unit under the TVaR capital allocation principle. Moreover, given the risk capital that the reinsurer holds, we express the default

probability of the reinsurer analytically. In case the reinsurer is in default, we determine analytical expressions for the amount of the aggregate reinsured unpaid losses and the unpaid losses of each reinsured line of business of the ceding insurer(s). These results are illustrated by numerical examples.

SALHI, YAHIA; THÉRON, PIERRE-E; TOMAS, JULIEN. *A credibility approach of the Makeham mortality law*. 61-96. Interest from life insurers to assess their portfolios' mortality risk has considerably increased. The new regulation and norms, Solvency II, shed light on the need of life tables that best reflect the experience of insured portfolios in order to quantify reliably the underlying mortality risk. In this context and following the work of H. Bühlmann and A. Gisler (*A course in credibility theory and its applications*. Springer, New York, 2005) and M.R. Hardy and H.H. Panjer (*ASTIN Bulletin* (1998) 28(2): 269-283), we propose a credibility approach which consists on reviewing, as new observations arrive, the assumption on the mortality curve. Unlike the methodology considered in Hardy and Panjer (1998) that consists on updating the aggregate deaths we have chosen to add an age structure on these deaths. Formally, we use a Makeham graduation model. Such an adjustment allows to add a structure in the mortality pattern which is useful when portfolios are of limited size so as to ensure a good representation over the entire age bands considered. We investigate the divergences in the mortality forecasts generated by the classical credibility approaches of mortality including Hardy and Panjer (1998) and the Poisson-Gamma model on portfolios originating from various French insurance companies.

STEIL, SARA; KOBUS, DETLEV; WOLF, JOCHEN. *The joint impact of fertility and unemployment on the level of state-aided pensions*. 97-111. Within the framework of Markov chains we study the joint impact of fertility and unemployment on the level of Riester annuities in the German market. Using raw data of the Federal Statistical Office and the National Employment Agency, we allow for dependencies between the two risk factors. For predefined scenarios we calculate the expected value and the standard deviation of the Riester annuities. We thereby aim at enhancing individual advice of policy holders focusing on customer needs.

TAYLOR, GREG C. *Comment on the paper 'The impact of covariates on a bonus-malus system: an application of Taylor's model' by Lemaire, Park & Wang*. 277-281. Comment on the paper: Lemaire, Jean; Park, Sojung Carol; Wang, Kili C (2015), The impact of covariates on a bonus-malus system: an application of Taylor's model. *European Actuarial Journal* (2015) 5(1): 1-10.

VIERKÖTTER, MATTHIAS. *Minimisation of penalty payments by investments and reinsurance*. 233-255. This paper considers an optimal investment and reinsurance problem for an insurance company, where the surplus follows a linear diffusion. Contrary to classical models the insurer can continue doing business even if the surplus becomes negative, but penalty payments occur depending on the level of the current surplus. The insurer can invest in n risky assets and reduce the insurance risk either by excess of loss or by proportional reinsurance. The aim is to find an optimal investment and reinsurance strategy which minimises the penalty payments. We consider various penalty functions and derive closed form solutions.

WEIDNER, W; TRANSCHEL, F W G; WEIDNER, R. *Classification of scale-sensitive telematic observables for risk-individual pricing*. 3-24. Using modern telematics technologies for car insurance, it is no particular challenge to produce an intractably large amount of kinematic and contextual information about driving profiles of motor vehicles. In order to evaluate this data with respect to both efficient and effective use in scoring and subsequent actuarial pricing, we propose a scale-sensitive approach that treats observations on semantically different levels. Furthermore we discuss the application of methods necessary to assess the information of different scale levels including signal processing, pattern recognition and Fourier analysis. In this way we show how maneuvers, trips and trip sections as well as the total insurance period can be analyzed to individually or collectively gain significantly scoreable insights into individual driving behaviour.

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Geneva Papers on Risk and Insurance

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ARNOLD-GAILLE, SÉVERINE; DEL CARMEN BOADO-PENAS, MARIA; GODÍNEZ OLIVARES, HUMBERTO. *Longevity risk in notional defined contribution pension schemes: a solution*. 24-52. Notional defined contribution pension schemes (NDCs) aim at reproducing the logic of a financial defined contribution plan under a pay-as-you-go framework. Of particular interest is how the accumulated capital of a deceased person is used when the death occurs prior to retirement. While in most countries this accumulated capital (called survivor dividend, SD) is kept by the scheme, in Sweden it is distributed among the same cohort survivors. This paper aims to analyse to what extent the SD kept by most NDCs can be used to cover an unexpected longevity increase. We develop formulas under different assumptions (constant or according to Lee-arter mortality improvements) to calculate the maximum mortality decrease a scheme can cover if the SD is not distributed. We also apply the formulas using Polish, Latvian and Swedish life tables and show that the non-distribution of the SD is a potential solution to cover the longevity risk of NDCs.

ASEERVATHAM, VIJAY; LEX, CHRISTOPH; SPINDLER, MARTIN. *How do unisex rating regulations affect gender differences in insurance premiums?* 128-160. As of 21 December 2012, the use of gender as an insurance rating category is prohibited in the EU. Any remaining pricing

disparities between men and women will now be traced back to the reasonable pricing of characteristics that happen to differ between the groups or to the pricing of characteristics that differ between sexes in a way that proxies for gender. Using data from an automobile insurer, we analyse how the standard industry approach of simply omitting gender from the pricing formula, which allows for proxy effects, differs from the benchmark for what prices would look like if direct gender effects were removed and other variables did not adjust as proxies. We find that the standard industry approach will likely be influenced by proxy effects for younger and older drivers. Our method can simply be applied to almost any setting where a regulator is considering a uniform pricing reform.

CHAN, WAI-SUM; LI, JOHNNY SIU-HANG; ZHOU, KENNETH Q; ZHOU, RUI. *Towards a large and liquid longevity market: a graphical population basis risk metric*. 118-127. Pension plan sponsors and annuity providers can offload their longevity risk exposures by trading securities that are linked to broad-based mortality indexes. However, a hedge constructed in this way is subject to population basis risk, arising from the difference in mortality improvements between the hedger's population and the reference population to which the security is linked. To address this problem, which is believed to be a major obstacle to market development, in this paper we contribute a graphical population basis risk metric. The graphical metric allows market participants to not only visually evaluate the extent of population basis risk, but also determine the most appropriate reference population. We illustrate this concept with a hypothetical example.

GATZERT, NADINE; KLOTZKI, UDO. *Enhanced annuities: drivers of and barriers to supply and demand*. 53-77. Enhanced annuities pay higher pensions than standard annuities in case of a reduced life expectancy and are very prominent in the U.K. insurance market but not in other markets. The aim of this paper is to study drivers of and barriers to supply and demand of enhanced annuities as well as potential market implications of their introduction, including implications for the standard immediate and deferred annuity markets, annuitisation rates and the so-called cannibalisation effect, which may arise within the portfolio of standard annuities because of the enhanced annuity offering. The analysis is based on a comprehensive literature review and an empirical survey in the German life insurance market, which is also intended to offer insight for other industrialised countries with a similar situation in regard to the demographic development and an increasing need for private pensions.

GUILLEMETTE, MICHAEL A; MARTIN, TERRANCE K, JR; CUMMINGS, BENJAMIN F; JAMES, RUSSELL N, III. *Determinants of the stated probability of purchase for longevity insurance*. 4-23. We study the determinants of the stated probability of purchase for a deferred annuity that pays out at age 80 or 85, which we reframe as "longevity insurance", using the Survey of Household Financial and Risk Management. Our results indicate that younger cohorts and women are more likely to express a desire to purchase longevity insurance in the future. The stated probability of purchase for longevity insurance was lower for respondents with greater home equity and higher coefficients of relative risk aversion. Our results may be of particular interest to policymakers, annuity companies and retirement plan providers.

PITACCO, ERMANNO. *Guarantee structures in life annuities: a comparative analysis*. 78-97. Life annuities constitute a large category of insurance and pension products, ranging from conventional annuities (immediate or deferred) to longevity-linked life annuities, sharing the aim of providing living benefits. The analysis of the guarantee structure aims at singling out the risks taken by the annuity provider, in particular the longevity risk, and the possibility of sharing these risks between annuitant and annuity provider.

SHIU, YUNG-MING. *Is reinsurance a substitute for or a complement to derivative usage? Evidence from the UK non-life insurance industry.* 161-178. Reinsurance and derivatives are tools in general use by insurers as the means of hedging their respective underwriting and investment risks. The primary aim of this study is to examine the relationship between reinsurance and derivative usage, a relationship which is tested based on a data set on U.K. non-life insurers covering the years 1994–2011. Consistent with the “substitution” hypothesis, we find strong evidence of a tendency among insurers with higher dependence on reinsurance (derivatives) to exhibit less reliance on derivatives (reinsurance). This result lends support to the view that, when making their risk management decisions, managers of such insurers will seek to determine the overall risk exposure of the firm.

TANAKA, SHUJI. *A proposal for redesigning social security: long-term care pension.* 98-117. I propose to replace the automatic adjustment system of pension benefits, embedded in the 2004 reform of the Japanese public pension scheme, with one providing for specific required care levels and thus assure the logical financial adjustment of long-term care insurance (LTCI) and public pensions. For this purpose, I introduce a multi-state Markov chain model and estimate the transition matrix combining the existent local experience data and nationwide public data. The following policy effect will be anticipated. If an LTCI beneficiary falls into a certain required care status, his or her required care benefit will need to be upgraded and the individual expense burden will increase. A similar approach is proposed by annuity products in the private sector such as the QLAC (qualified longevity annuity contract) in the U.S. and “life care pensions” in Britain.

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ALTUNTAS, MUHAMMED; RAUCH, JANNES; WENDE, SABINE. *Strategic group performance and dynamics under different economic conditions.* 325-347. We analyse strategic groups in the German insurance market. We use cluster analysis to subdivide insurance groups into strategic groups. Furthermore, we analyse whether strategic group affiliation can affect the performance of the insurance groups’ property-liability subsidiaries. In addition, we examine the consequences of the financial crisis of 2008 on the competitive situation in the German insurance sector and examine whether changes in strategic group affiliation can be considered as a consequence of the financial crisis. Using a data set of 829 firm-year observations for the years 2004–2012, our results indicate the existence of three strategic group in the German insurance sector. In addition, we find that performance differences at the subsidiary level can be attributed to strategic group affiliation. Furthermore, we do not find evidence that the financial crisis induced changes in strategic group affiliation.

BENDIG, MIRKO; ARUN, THANKROM. *Uptake of multiple microinsurance schemes: evidence from Sri Lanka.* 205-224. Since it is common among households to use more than one form of

microinsurance, this paper estimates the uptake of different kinds of microinsurance by the same population. We use a multivariate probit model which examines the participation in the different forms of insurance simultaneously. By doing this, we can establish whether participation patterns in different types of microinsurance options indicate if the participation in specific insurance schemes is complementary or a substitute. We establish that membership of a microfinance institution means that households are more likely to have purchased an insurance policy. Furthermore, the study describes a need for more inclusive and composite packages of microinsurance products for greater financial inclusion of the poor.

JANGLE, NIHAR; MEHRA, MAMTA; DROR, DAVID M. “*Climate cost of cultivation*”: a new crop index method to quantify farmers’ cost of climate change exemplified in rural India. 280-306. We model the impact of agricultural droughts with a new multi-parameter index (using both climatic and non-climatic parameters) and propose a new risk transfer solution for crop insurance, called Climate Cost of Cultivation (CCC). We used 1979/80 to 2012/13 data relevant for wheat in Bihar, India to test the variation in the CCC values. The variance (risk to farmer) increased significantly in the second half of the period (two-tailed F-test, $p = 0.00045$). We examine the efficiency of CCC by comparing it to typical index insurance (TII), and both indices to wheat yield data (2000/01 to 2012/13). The correlation of CCC index payouts with actual yield losses is improved by a factor of ~ 3.9 over TII results (76.0 per cent, compared with 19.6 per cent). The pure risk premium of the CCC index is lower by around 90 per cent than the premium of the TII. We also elaborate a method to quantify the premium’s climate change cost component.

LIU, HUI; SHIU, YUNG-MING; LIU, TSUNG-CHI. *Reinsurance and liquidity: evidence from the United Kingdom general insurance industry*. 307-324. This paper aims to simultaneously examine the effect of liquidity on reinsurance use and the reverse causality of reinsurance on liquidity. Using a sample of UK general insurers from 1994 to 2011, we find that insurers with higher liquidity tend to purchase more reinsurance, and those with higher reinsurance dependence tend to maintain higher liquidity. Our data indicates that the cash-constraint argument dominates the substitution argument. We further find an inverted U-shaped relation between reinsurance and liquidity. Particular attention should be paid to the less liquid insurers that purchase less reinsurance because they have both less underwriting and liquidity risk management, and thus are exposed to a higher level of insolvency risk.

RADERMACHER, RALF; SRIVASTA, SIDDHARTH; WALSHAM, MATTHEW; SAO, CHHORN; PAOLUCCI, FRANCESCO. *Enhancing the inclusion of vulnerable and high-risk groups in demand-side health financing schemes in Cambodia: a concept for a risk-adjusted subsidy approach*. 244-258. Efforts are currently under way in Cambodia to expand the population coverage of social health protection schemes (health equity funds and voluntary insurance). Aligning the benefit packages for members of such schemes poses particular challenges in relation to the insurance component, as the financing of direct benefits in the insurance relies largely on the collection of voluntary premiums. This paper develops the concept of a targeted “risk-adjusted subsidy” approach to address this issue. Data on the health-seeking behaviour of insured households from Kampong Thom district over the course of one year (2010) are used to illustrate the concept. To retain the currently applied community rating and set incentives for cost effectiveness in administrative costs, as well as to avoid cream skimming (focusing on “good risks”), a risk-adjustment mechanism is proposed that would provide ex ante subsidies to insurance schemes according to the expected additional cost of a person joining the scheme.

Although the concept is developed using the example of Cambodia, it is equally applicable to all developing countries facing fragmented risk pools while aiming for universal health coverage.

SAVITHA, BASRI; KIRAN, K B. *Illness makes credit sick: can health insurance rescue the poor from exploitative credit?* 184-204. Health shocks cripple poor households through hardship financing and impoverishment. Borrowing from non-market sources is the most common strategy used by these households, which eventually pushes them into a debt trap. Micro health insurance (MHI) is expected to reduce the reliance on these sources of finance by ensuring financial protection. We use the data from a cross-sectional study undertaken in Karnataka to investigate any association between MHI and non-market credit during health shocks. The sample size was 1,146 consisting of 416 insured households and the remaining being uninsured. The analysis of the data shows inadequate risk protection provided by MHI giving rise to borrowing, sale of assets and liquidation of savings by insured individuals. Yet, they relied less on usurious credit compared with uninsured individuals. This finding not only substantiates the importance of MHI in health-care financing but also highlights the need for affordable and comprehensive financing mechanisms to replace non-market institutions with formal insurance.

WOODARD, JOSHUA D; SHEEN, ANDREW; MUDE, ANDREW G. *A spatial econometric approach to designing and rating scalable index insurance in the presence of missing data.* 259-279. Index-Based Livestock Insurance has emerged as a promising market-based solution for insuring livestock against drought-related mortality. The objective of this work is to develop an explicit spatial econometric framework to estimate insurable indexes that can be integrated within a general insurance pricing framework. We explore the problem of estimating spatial panel models when there are missing dependent variable observations and cross-sectional dependence, and implement an estimable procedure which employs an iterative method. We also develop an out-of-sample efficient cross-validation mixing method to optimise the degree of index aggregation in the context of spatial index models.

ZHANG, YUEHUA; ZHU, XI; TURVEY, CALUM G. *On the impact of agricultural livestock microinsurance on death-loss, production and vaccine use: observations from a quasi-natural experiment in China.* 225-243. Moral hazard remains a major concern in microinsurance markets in most developing countries. However, it is hard to find good measures and control individual heterogeneity to make reliable tests. We address these problems by taking advantage of a natural experiment due to an insurance company's policy change in Deqing County China in 2009 and 2010. We investigate the effect of pig insurance on death loss, production and vaccine use based on a detailed household survey. Difference-in-differences and propensity score-matching estimators show that insurance's effect on mortality and vaccine use is not significant for both hogs and sows. Thus, there is no evidence of moral hazard. However, the insurance does have a positive impact on hog production, but not for sows. These results show that moral hazard problems should not be the main barrier to developing the livestock microinsurance market.

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BOBTCHEFF, CATHERINE; CHANEY, THOMAS; GOLLIER, CHRISTIAN. *Analysis of systemic risk in the insurance industry.* 73-106. In this paper, we discuss the systemic relevance of the

insurance sector. Systemic risk is defined as the propensity of a financial institution to be undercapitalised when the financial system as a whole is undercapitalised. By the law of large numbers, traditional lines of insurance with idiosyncratic non-catastrophic risks cannot be systemic. On the contrary, undiversified insurers specialised in activities whose insured risks are highly correlated with GDP are systemic. In the life insurance sector, some contractual clauses such as unhedged minimum guarantees and free options to surrender raise the chance of systemic relevance. On the contrary, life insurers satisfying the classic solvency capital requirements contribute to the liquidity of financial markets thanks to the long-termist approach of their portfolio management. Finally, using historical data in the U.S. on the contribution of different sectors to the aggregate volatility of the economy, we show that investment banking is almost twice as volatile as aggregate GDP, while insurance is one fifth as volatile as aggregate GDP. The insurance sector thus appears to be a stabilising force of the economy.

CHAN, LINUS F-S; HUANG, YI-CHIEH; TZENG, LARRY Y. *Who obtains greater discounts on automobile insurance premiums?* 48-72. Insurance purchasers obtain varied discounts for insurance. This paper examines what drives these differences, specifically whether the loss probability and the wealth of the insured affect the size of the premium discount in automobile insurance. To describe a bargain between a client and an insurer over premiums and coverage, we first develop a sequential insurance bargaining game where the client has an outside option to bargain with another insurer. We find that the equilibrium involves full coverage and, based on the results of comparative statics, we propose hypotheses regarding the effects of the loss probability and the wealth of the insured on the size of the premium discount. We then use a unique data set of 85,806 observations of Taiwanese automobile liability insurance for property damage to empirically test the predictions. After controlling for underwriting and macroeconomic variables, we find that both (1) the insured with a lower claim probability (as a proxy for the insured with a lower loss probability) and (2) the insured with a higher salvage value car (as a proxy for the wealthier insured) receive a greater premium discount. These results support our theoretical results.

DENUIT, MICHEL M; EECKHOUDT, LOUIS; MEYER, JACK. *Tradeoffs for downside risk-averse decision-makers and the self-protection decision.* 19-47. In addition to risk aversion, decision-makers tend to be also downside risk averse. Besides the usual size for risk trade-off, this allows several other trade-offs to be considered. The decision to increase the level of self-protection generates five trade-offs each involving an unfavourable downside risk increase and an accompanying beneficial change. Five stochastic orders that correspond to these trade-offs are defined, characterised and used to prove comparative static theorems that provide information concerning the self-protection decision. The five stochastic orders are general in nature and can be applied in any decision model where downside risk aversion is assumed.

HENRIET, DOMINIQUE; KLIMENKO, NATALIYA; ROCHET, JEAN-CHARLES. *The dynamics of insurance prices.* 2-18. We develop a continuous-time general-equilibrium model to rationalise the dynamics of insurance prices in a competitive insurance market with financial frictions. Insurance companies choose underwriting and financing policies to maximise shareholder value. The equilibrium price dynamics are explicit, which allows simple numerical simulations and generates testable implications. In particular, we find that the equilibrium price of insurance is (weakly) predictable and the insurance sector always realises positive expected profits. Moreover, rather than true cycles, insurance prices exhibit asymmetric reversals caused by the reflection of the aggregate capacity process at the dividend and recapitalisation boundaries.

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ASIMIT, ALEXANDRU V; BADESCU, ALEXANDRU M; HABERMAN, STEVEN; KIM, EUN-SEOK. *Efficient risk allocation within a non-life insurance group under Solvency II regime*. 69-76. Intra-group transfers are risk management tools that are usually widely used to optimise the risk position of an insurance group. In this paper, it is shown that premium and liability transfers could be optimally made in such a way as to reduce the amount of Technical Provisions and Minimum Capital Requirement for the entire insurance conglomerate. These levels of required capital represent the minimal amount that needs to be held by the insurance group without regulator intervention, according to the Solvency II regulation. We assume that only proportional risk transfers are feasible, since such transfers are not difficult to administer for a large scaled insurance group, as is always the case. In addition, any risk shifting should be made for commercial purposes in order to be considered acceptable by the local regulators that impose restrictions on how much the assets within an insurance group are fungible. Our numerical examples illustrate the efficiency of the optimal proportional risk transfers which can easily be implemented, in terms of computation, in any well-known solver even for an insurance conglomerate with many subsidiaries. We found that our proposed optimal proportional allocations are more beneficial for large insurance group, since the relative reduction in capital requirement tends to be small, whereas the gain in absolute terms is quite significant for large scaled insurance group.

BOHNERT, ALEXANDER; GATZERT, NADINE; KOLB, ANDREAS. *Assessing inflation risk in non-life insurance*. 86-96. Inflation risk is of high relevance in non-life insurers' long-tail business and can have a major impact on claims reserving. In this paper, we empirically study claims inflation with focus on automobile liability insurance based on a data set provided by a large German non-life insurance company. The aim is to obtain empirical insight regarding the drivers of claims inflation risk and its impact on reserving. Toward this end, we use stepwise multiple regression analysis to identify relevant drivers based on economic indices related to health costs and consumer prices, amongst others. We further study the impact of (implicitly and explicitly) predicting calendar year inflation effects on claims reserves using stochastic inflation models. Our results show that drivers for claims inflation can considerably vary for different lines of business and emphasize the importance of explicitly dealing with (stochastic) claims inflation when calculating reserves.

FUZI, MOHD FADZLI MOHD; JEMAIN, ABDUL AZIZ; ISMAIL, NORISZURA. *Bayesian quantile regression model for claim count data*. 124-137. Quantile regression model estimates the relationship between the quantile of a response distribution and the regression parameters, and has been developed for linear models with continuous responses. In this paper, we apply Bayesian quantile regression model for the Malaysian motor insurance claim count data to study the effects

of change in the estimates of regression parameters (or the rating factors) on the magnitude of the response variable (or the claim count). We also compare the results of quantile regression models from the Bayesian and frequentist approaches and the results of mean regression models from the Poisson and negative binomial. Comparison from Poisson and Bayesian quantile regression models shows that the effects of vehicle year decrease as the quantile increases, suggesting that the rating factor has lower risk for higher claim counts. On the other hand, the effects of vehicle type increase as the quantile increases, indicating that the rating factor has higher risk for higher claim counts.

JOST, PETER-J. *Competitive insurance pricing with complete information, loss-averse utility and finitely many policies*. 11-21. In a recent paper, Ramsay and Oguledo (2012) [C M Ramsay, V I Oguledo (2012), Insurance pricing with complete information, state-dependent utility, and production costs, Insurance Mathematics and Economics (2012) 50: 462-469] show that in a competitive insurance market with complete information about individuals' accident probabilities and production costs, which are proportional to the amount of insurance purchased and to the premium charged, only individuals whose accident probability is in a medium range are insurable and desire insurance. The purpose of this paper is to complement the analysis of Ramsay and Oguledo by considering production costs which are proportional to the number of policies offered by an insurer. In addition to the result of Ramsay and Oguledo we show that the group of individuals who obtain insurance is partitioned into several subgroups, where each subgroup is offered the same insurance policy. To derive this result we introduce the concept of incentive compatibility which ensures that an individual has no incentive to buy another policy. Assuming that individuals have loss-averse utility, we fully characterize the boundaries of these subgroups as the result of an undercutting process in premiums between the insurers.

KIM, SO-YEUN; WILLMOT, GORDON E. *On the analysis of ruin-related quantities in the delayed renewal risk model*. 77-85. This paper first explores the Laplace transform of the time of ruin in the delayed renewal risk model. We show that $G\delta d(u)$, the Laplace transform of the time of ruin in the delayed model, also satisfies a defective renewal equation and use this to study the Cramer-Lundberg asymptotics and bounds of $G\delta d(u)$. Next, the paper considers the stochastic decomposition of the residual lifetime of maximal aggregate loss and more generally $L\delta d$ in the delayed renewal risk model, using the framework equation introduced in Kim and Willmot (2011) [Kim, S., Willmot, G.E. (2011), The proper distribution function of the deficit in the delayed renewal risk model, Scandinavian Actuarial Journal 2: 118-137] and the defective renewal equation for the Laplace transform of the time of ruin. As a result of the decomposition, we propose a way to calculate the mean and the moments of the proper deficit in the delayed renewal risk model. Lastly, closed form expressions are derived for the Gerber-Shiu function in the delayed renewal risk model with the distributional assumption of time until the first claim and simulation results are included to assess the impact of different distributional assumptions on the time until the first claim.

KOLKOVSKA, EKATERINA T; MARTÍN-GONZÁLEZ, EHYTER M. *Gerber-Shiu functionals for classical risk processes perturbed by an α -stable motion*. 22-28. We study the Gerber-Shiu functional of the classical risk process perturbed by a spectrally negative α -stable motion. We provide representations of the scale functions of the process as an infinite series of convolutions of given functions. This, together with a result from Biffis and Kyprianou (2010) [Biffis, E., Kyprianou, A.E. (2010), A note on scale functions and the time value of ruin for Lévy insurance risk processes, Insurance: Mathematics & Economics 46(1): 85-91], allows us to obtain a

representation of the Gerber-Shiu functional as an infinite series of convolutions. Moreover, we calculate the Laplace transform and derive a defective renewal equation for the Gerber-Shiu functional, thus extending previous work of Furrer (1998) [Furrer, H. (1998), Risk processes perturbed by α -stable Lévy motion, Scandinavian Actuarial Journal (1998) 1: 59-74] and of Tsai and Willmot (2002) [Tsai, C.C., Willmot, G.E. (2002), A generalized defective renewal equation for the surplus process perturbed by diffusion, Insurance Mathematics & Economics 30(1): 51-66]. We also obtain asymptotic expressions for the joint tail distribution of the severity of ruin and the surplus before ruin.

LIN, TZULING; TSAI, CARY CHI-LIANG. *Hedging mortality/longevity risks of insurance portfolios for life insurer/annuity provider and financial intermediary.* 44-58. In this paper, we propose two risk hedge schemes in which a life insurer (an annuity provider) can transfer mortality (longevity) risk of a portfolio of life (annuity) exposures to a financial intermediary by paying the hedging premium of a mortality-linked security. The optimal units of the mortality-linked security which maximize hedge effectiveness for a life insurer (an annuity provider) can be derived as closed-form formulas under the risk hedge schemes. Numerical illustrations show that the risk hedge schemes can significantly hedge the downside risk of loss due to mortality (longevity) risk for the life insurer (annuity provider) under some stochastic mortality models. Besides, finding an optimal weight of a portfolio of life and annuity business, the financial intermediary can reduce the sensitivity to mortality rates but the model risk; a security loading may be imposed on the hedge premium for a higher probability of gain to compensate the financial intermediary for the inevitable model risk.

LIU, CONG; ZHENG, HARRY. *Asymptotic analysis for target asset portfolio allocation with small transaction costs.* 59-68. In this paper we discuss the asset allocation in the presence of small proportional transaction costs. The objective is to keep the asset portfolio close to a target portfolio and at the same time to reduce the trading cost in doing so. We derive the variational inequality and prove a verification theorem. Furthermore, we apply the second order asymptotic expansion method to characterize explicitly the optimal no transaction region when the transaction cost is small and show that the boundary points are asymmetric in relation to the target portfolio position, in contrast to the symmetric relation when only the first order asymptotic expansion method is used, and the leading order is a constant proportion of the cubic root of the small transaction cost. In addition, we use the asymptotic results for the boundary points and obtain an expansion for the value function. The results are illustrated in the numerical example.

NICHIL, GEOFREY; VALLOIS, PIERRE. *Provisioning against borrowers default risk.* 29-43. This paper focuses on the risk of loan default from the point of view of an insurer required to indemnify a bank for losses resulting from a borrower defaulting. The main objective of this paper is to model the provision (or claim reserve) against the risk of borrowers defaulting. Unlike traditionally used models, our model depends on specific information concerning the borrowers (amount borrowed and term of loan). Our approach will also take into account three kinds of dependence: the dependence between each claim amount (by taking into account the real estate price), the dependence between the date of default and the claim amount, and the dependence between the number of defaults and the claim amount. Both theoretical and applied, our model allows the calculation of the mean, the variance, and the law of the provision. The amount of data available allows us to estimate all the parameters and to calculate the mean and the variance plus the quantiles of the provision.

PELSSER, ANTOON A J; GHALEHJOOGHI, AHMAD SALAHNEJHAD. *Time-consistent actuarial valuations*. 97-112. Time-consistent valuations (i.e. pricing operators) can be created by backward iteration of one-period valuations. In this paper we investigate the continuous-time limits of well-known actuarial premium principles when such backward iteration procedures are applied. This method is applied to an insurance risk process in the form of a diffusion process and a jump process in order to capture the heavy tailed nature of insurance liabilities. We show that in the case of the diffusion process, the one-period time-consistent Variance premium principle converges to the non-linear exponential indifference price. Furthermore, we show that the Standard-Deviation and the Cost-of-Capital principle converge to the same price limit. Adding the jump risk gives a more realistic picture of the price. Furthermore, we no longer observe that the different premium principles converge to the same limit since each principle reflects the effect of the jump differently. In the Cost-of-Capital principle, in particular the VaR operator fails to capture the jump risk for small jump probabilities, and the time-consistent price depends on the distribution of the premium jump.

WEI, LI; YUAN, ZHONGYI. *The loss given default of a low-default portfolio with weak contagion*. 113-123. In this paper we study the loss given default (LGD) of a low default portfolio (LDP), assuming that there is weak credit contagion among the obligors. We characterize the credit contagion by a Sarmanov dependence structure of the risk factors that drive the obligors' default, where the risk factors are assumed to be heavy tailed. From a new perspective of asymptotic analysis, we derive a limiting distribution for the LGD. As a consequence, an approximation for the entire distribution, in contrast to just the tail behavior, of the LGD is obtained. We show numerical examples to demonstrate the limiting distribution. We also discuss possible applications of the limiting distribution to the calculation of moments and the Value at Risk (VaR) of the LGD.

ZENG, YAN; LI, DANPING; GU, AILING. *Robust equilibrium reinsurance-investment strategy for a mean-variance insurer in a model with jumps*. 138-152. This paper analyzes the equilibrium strategy of a robust optimal reinsurance-investment problem under the mean-variance criterion in a model with jumps for an ambiguity-averse insurer (AAI) who worries about model uncertainty. The AAI's surplus process is assumed to follow the classical Cramér-Lundberg model, and the AAI is allowed to purchase proportional reinsurance or acquire new business and invest in a financial market to manage her risk. The financial market consists of a risk-free asset and a risky asset whose price process is described by a jump-diffusion model. By applying stochastic control theory, we establish the corresponding extended Hamilton-Jacobi-Bellman (HJB) system of equations. Furthermore, we derive both the robust equilibrium reinsurance-investment strategy and the corresponding equilibrium value function by solving the extended HJB system of equations. In addition, some special cases of our model are provided, which show that our model and results extend some existing ones in the literature. Finally, the economic implications of our findings are illustrated, and utility losses from ignoring model uncertainty, jump risks and prohibiting reinsurance are analyzed using numerical examples.

ZHANG, KONG-SHENG; LIN, JIN-GUAN; XU, PEI-RONG. *A new class of copulas involving geometric distribution: estimation and applications*. 1-10. Copula is becoming a popular tool for modeling the dependence structure among multiple variables. Commonly used copulas are Gaussian, t and Gumbel copulas. To further generalize these copulas, a new class of copulas, referred to as geometric copulas, is introduced by adding geometric distribution into the existing copulas. The interior-point penalty function algorithm is proposed to obtain maximum likelihood

estimation of the parameters of geometric copulas. Simulation studies are carried out to evaluate the efficiency of the proposed method. The proposed estimation method is illustrated with workers' compensation insurance data and exchange rate series data.

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BERNARD, CAROLE; KWAK, MINSUK. *Semi-static hedging of variable annuities*. 173-186.

This paper focuses on hedging financial risk in variable annuities with guarantees. We show that insurers should incorporate the specificity of the periodic payment of variable annuities fees to best hedge embedded guarantees and should focus on hedging the net liability. We develop a new hedging strategy based on semi-static hedging techniques, which takes into account the periodically collected fees, and confirm that it is more effective than delta-hedging with same rebalancing dates, as well as traditional semi-static hedging strategies that do not consider the specificity of the payments of fees in their optimization. It is also verified that short-selling or using put options as hedging instruments allows more effective hedging.

CHEN, SHUMIN; WANG, XI; DENG, YINGLU; ZENG, YAN. *Optimal dividend-financing strategies in a dual risk model with time-inconsistent preferences*. 27-37.

In this paper, we consider an optimal dividend-financing problem for a company whose capital reserve is described by the dual of classical risk model. We assume that the manager of the company has time-inconsistent preferences, which are described by a quasi-hyperbolic discount function, and that financing is permitted to prevent the company from going bankrupt. The manager's objective is to maximize the expected cumulative dividend payments minus financing costs. We solve the optimization problems for a naive manager and a sophisticated manager, and obtain explicit solutions for both managers. Our results show that the manager with time-inconsistent preferences tends to pay out dividends earlier. We also present some economic implications and sensitivity analysis for our results.

CHOO, WEIHAO; DE JONG, PIET. *Insights to systematic risk and diversification across a joint probability distribution*. 142-150.

This paper analyses and develops insights to systematic risk and diversification when random, imperfectly dependent, losses are aggregated. Systematic risk and diversification are shown to vary across layers of component losses according to local dependence and volatility structures. Systematic risk is high and diversification is weak overall if high risk layers are heavily dependent on the aggregate loss. This result explains weak diversification observed in financial markets despite weak to moderate correlations overall. A coherent risk setup is assumed in this paper, where risks are measured using distortion and allocated using the Euler principle.

DE KORT, J; VELLEKOOP, M H. *Term structure extrapolation and asymptotic forward rates*. 107-119.

We investigate different inter- and extrapolation methods for term structures under different constraints in order to generate market-consistent estimates which describe the asymptotic behavior of forward rates. Our starting point is the method proposed by Smith and Wilson, which is used by the European insurance supervisor EIOPA. We use the characterization of the Smith-Wilson class of interpolating functions as the solution to a functional optimization

problem to extend their approach in such a way that forward rates will converge to a value which is an outcome of the optimization process. Precise conditions are stated which guarantee that the optimization problems involved are well-posed on appropriately chosen function spaces. As a result, a well-defined optimal asymptotic forward rate can be derived directly from prices and cashflows of traded instruments. This allows practitioners to use raw market data to extract information about long term forward rates, as we will show in a study which analyzes historical EURIBOR swap data.

DICKSON, DAVID C M. *A note on some joint distribution functions involving the time of ruin.* 120-124. In a recent paper, Willmot (2015) [Willmot, G.E. (2015), On a partial differential equation of Seal's type, Insurance Mathematics and Economics 62: 54-61] derived an expression for the joint distribution function of the time of ruin and the deficit at ruin in the classical risk model. We show how his approach can be applied to obtain a simpler expression, and by interpreting this expression by probabilistic reasoning we obtain solutions for more general risk models. We also discuss how some of Willmot's results relate to existing literature on the probability and severity of ruin.

DIERS, DOROTHEA; LINDE, MARC; HAHN, LUKAS. *Addendum to 'The multi-year non-life insurance risk in the additive reserving model': Quantification of multi-year non-life insurance risk in chain ladder reserving models.* 187-199. This is the first study to derive closed-form analytical expressions for multi-year non-life insurance risk in the chain ladder model. Extending on previous research on the additive reserving model, we define multi-year risk via prediction errors of multi-year claims development results including both observed and future accident years. A resampling argument and a first-order Taylor approximation address the quantification of estimation errors and multiplicative dependencies in the chain ladder framework, respectively. From our generalized multi-year approach, we deduce estimators for reserve and premium risks in multi-year view and their implicit correlation. We reproduce well-known results from literature for the special cases of one-year and ultimo view. Further, we comment on how to obtain estimators for generalized versions of the chain ladder method. A case study demonstrates the applicability of our analytical formulae.

FENG, RUNHUAN; HUANG, HUAXIONG. *Statutory financial reporting for variable annuity guaranteed death benefits: market practice, mathematical modeling and computation.* 54-64. As more regulatory reporting requirements for equity-linked insurance move towards dependence on stochastic approaches, insurance companies are experiencing increasing difficulty with detailed forecasting and more accurate risk assessment based on Monte Carlo simulations. While there is vast literature on pricing and valuations of various equity-linked insurance products, very few have focused on the challenges of financial reporting for regulatory requirement and internal risk management. Most insurers use either simulation-based spreadsheet calculations or employ third-party vendor software packages. We intend to use a basic variable annuity death benefit as a model example to decipher the common mathematical structure of US statutory financial reporting. We shall demonstrate that alternative deterministic algorithms such as partial differential equation (PDE) methods can also be used in financial reporting, and that a fully quantified model allows us to compare alternatives of risk metrics for financial reporting.

HOUGAARD, JENS LETH; SMILGINS, ALEKSANDRS. *Risk capital allocation with autonomous subunits: the Lorenz set.* 151-157. Risk capital allocation problems have been widely discussed in the academic literature. We consider a set of independent subunits collaborating in order to

reduce risk: that is, when subunit portfolios are merged a diversification benefit arises and the risk of the group as a whole is smaller than the sum of the risks of the individual subunits. The question is how to allocate the risk capital of the group among the subunits in a fair way. In this paper we propose to use the Lorenz set as an allocation method. We show that the Lorenz set is operational and coherent. Moreover, we propose three fairness tests related directly to the problem of risk capital allocation and show that the Lorenz set satisfies all three tests in contrast to other well-known coherent methods. Finally, we discuss how to deal with non-uniqueness of the Lorenz set.

JARNER, SØREN FIIG; KRONBORG, MORTEN TOLVER. *Entrance times of random walks: with applications to pension fund modeling*. 1-20. The purpose of the paper is twofold. First, we consider entrance times of random walks, i.e. the time of first entry to the negative axis. Partition sum formulas are given for entrance time probabilities, the n th derivative of the generating function, and the n th falling factorial entrance time moment. Similar formulas for the characteristic function of the position of the random walk both conditioned on entry and conditioned on no entry are also established. Second, we consider a model for a with-profits collective pension fund. The model has previously been studied by approximate methods, but we give here an essentially complete theoretical description of the model based on the entrance time results. We also conduct a mean–variance analysis for a fund in stationarity. To facilitate the analysis we devise a simple and effective exact simulation algorithm for sampling from the stationary distribution of a regenerative Markov chain.

KANNO, MASAYASU. *The network structure and systemic risk in the global non-life insurance market*. 38-53. This paper contributes to the literature on systemic risk by assessing the systemic importance of insurers in the global non-life insurance market. First, we estimate the bilateral reinsurance claims matrix using the aggregate outstanding reinsurance data from ISIS and theoretically analyze the interconnectedness in the global reinsurance network using network indicators. The robustness of the estimated matrix is fully assured by sensitivity analysis. Second, we theoretically analyze the contagious defaults introducing the Eisenberg–Noe framework. Reinsurers play a dominant role in the reinsurance network and most of them are included in our data sample. The network analysis finds that some reinsurers with large centrality measures are central in the hierarchical structure of the network. The default analysis shows the occurrences of many stand-alone defaults and only one contagious default via the global reinsurance network after the global financial crisis. In addition, one stress test based on a hypothetical severe stress scenario predicts a few occurrences of contagious defaults in the future. It follows from these analyses that systemic risk via the global reinsurance network is relatively restricted in the global non-life insurance market. In conclusion, our methodology would help supervisory authorities develop an assessment approach for interconnectedness in the global reinsurance network and aid the implementation of insurer stress tests for default contagion.

MOUSA, A S; PINHEIRO, D; PINTO, A A. *Optimal life-insurance selection and purchase within a market of several life-insurance providers*. 133-141. We consider the problem faced by a wage-earner with an uncertain lifetime having to reach decisions concerning consumption and life-insurance purchase, while investing his savings in a financial market comprised of one risk-free security and an arbitrary number of risky securities whose prices are determined by diffusive linear stochastic differential equations. We assume that life-insurance is continuously available for the wage-earner to buy from a market composed of a fixed number of life-insurance companies offering pairwise distinct life-insurance contracts. We characterize the optimal consumption,

investment and life-insurance selection and purchase strategies for the wage-earner with an uncertain lifetime and whose goal is to maximize the expected utility obtained from his family consumption, from the size of the estate in the event of premature death, and from the size of the estate at the time of retirement. We use dynamic programming techniques to obtain an explicit solution in the case of discounted constant relative risk aversion (CRRA) utility functions.

SANDERS, LISANNE; MELENBERG, BERTRAND. *Estimating the joint survival probabilities of married individuals*. 88-106. We estimate the joint survival probability of spouses using a large random sample drawn from a Dutch census. As benchmarks we use two bivariate Weibull models. We consider more flexible models, using a semi-nonparametric approach, by extending the independent Weibull distribution using squared polynomials. Also based on a nonparametric comparison, we find that extending the independent Weibull distribution by a squared third order polynomial shows the best performance. We illustrate our model by calculating remaining life expectancies and annuity values. We find that the husbands life expectancy at birth is generally increasing with his wives age of death and the wives life expectancy at birth is generally increasing with her husbands age of death. Ignoring the dependence between the remaining lifetimes of spouses may lead to an underestimation of the value of a joint annuity and an overestimation of the value of a single-life annuity, but less than suggested on the basis of the previous literature.

SUN, JINGYUN; LI, ZHONGFEI; ZENG, YAN. *Precommitment and equilibrium investment strategies for defined contribution pension plans under a jump-diffusion model*. 158-172. In this paper, we study an optimal investment problem under the mean-variance criterion for defined contribution pension plans during the accumulation phase. To protect the rights of a plan member who dies before retirement, a clause on the return of premiums for the plan member is adopted. We assume that the manager of the pension plan is allowed to invest the premiums in a financial market, which consists of one risk-free asset and one risky asset whose price process is modeled by a jump-diffusion process. The precommitment strategy and the corresponding value function are obtained using the stochastic dynamic programming approach. Under the framework of game theory and the assumption that the manager's risk aversion coefficient depends on the current wealth, the equilibrium strategy and the corresponding equilibrium value function are also derived. Our results show that with the same level of variance in the terminal wealth, the expected optimal terminal wealth under the precommitment strategy is greater than that under the equilibrium strategy with a constant risk aversion coefficient; the equilibrium strategy with a constant risk aversion coefficient is revealed to be different from that with a state-dependent risk aversion coefficient; and our results can also be degenerated to the results of He and Liang (2013b) [He, L., Liang, Z.X. (2013), Optimal investment strategy for the DC plan with the return of premiums clauses in a mean-variance framework, Insurance Mathematics and Economics 53(3): 643-649] and Björk et al. (2014) [T Björk, A Murgoci, XY Zhou (2014), Mean-variance portfolio optimization with state dependent risk aversion, Mathematical Finance 24(1): 1-24]. Finally, some numerical simulations are provided to illustrate our derived results.

YE, WUYI; ZHU, YANGGUANG; WU, YUEHUA; MIAO, BAIQI. *Markov regime-switching quantile regression models and financial contagion detection*. 21-26. In this paper, we propose a Markov regime-switching quantile regression model, which considers the case where there may exist equilibria jumps in quantile regression. The parameters are estimated by the maximum likelihood estimation (MLE) method. A simulation study of this new model is conducted covering many scenarios. The simulation results show that the MLE method is efficient in estimating the model parameters. An empirical analysis is also provided, which focuses on the detection of

financial crisis contagion between United States and some European Union countries during the period of sub-prime crisis from the angle of financial risk. The degree of financial contagion between markets is subsequently measured by utilizing the quantile regression coefficients. The empirical results show that in a crisis situation, the interdependence between United States and European Union countries dramatically increases.

ZHANG, XIN; MENG, HUI; ZENG, YAN. *Optimal investment and reinsurance strategies for insurers with generalized mean-variance premium principle and no-short selling*. 125-132. This paper analyzes the optimal investment and reinsurance strategies for insurers with a generalized mean-variance premium principle. The surplus process of the insurer is described by the diffusion model which is an approximation of the classical Cramér-Lundberg model. The insurer can purchase reinsurance and invest her surplus in a financial market consisting of a risk-free asset and multiple risky assets. The insurer is not allowed to short sell the risky assets. Two optimization problems, maximizing the expected utility function of terminal wealth and minimizing the probability of ruin, are considered. We first derive the form of optimal reinsurance for the two optimization problems. Then, by using the stochastic dynamic programming, we obtain the closed-form expressions of optimal investment and reinsurance strategies and optimal value functions for the two optimization problems. We find that our results are more general than some ones in the existing literature.

ZHENG, XIAOXIAO; ZHOU, JIEMING; SUN, ZHONGYANG. *Robust optimal portfolio and proportional reinsurance for an insurer under a CEV model*. 77-87. We investigate a robust optimal portfolio and reinsurance problem under a Cramér-Lundberg risk model for an ambiguity-averse insurer (AAI), who worries about uncertainty in model parameters. Assume that the AAI is allowed to purchase proportional reinsurance and invest his (or her) surplus in a financial market consisting of one risk-free asset and one risky asset whose price is modeled by a constant elasticity of variance (CEV) model. Using techniques of stochastic control, we first derive the closed-form expressions of the optimal strategies and the corresponding value functions for exponential utility function both in the classic compound Poisson risk process and its diffusion approximation, and then the verification theorem is given. Finally, we present numerical examples to illustrate the effects of model parameters on the optimal investment and reinsurance strategies.

ZHUANG, SHENG CHAO; WENG, CHENGGUO; TAN, KEN SENG; ASSA, HIRBOD. *Marginal Indemnification Function formulation for optimal reinsurance*. 65-76. In this paper, we propose to combine the Marginal Indemnification Function (MIF) formulation and the Lagrangian dual method to solve optimal reinsurance model with distortion risk measure and distortion reinsurance premium principle. The MIF method exploits the absolute continuity of admissible indemnification functions and formulates optimal reinsurance model into a functional linear programming of determining an optimal measurable function valued over a bounded interval. The MIF method was recently introduced to analyze the reinsurance model but without premium budget constraint. In this paper, a Lagrangian dual method is applied to combine with MIF to solve for optimal reinsurance solutions under premium budget constraint. Compared with the existing literature, the proposed integrated MIF-based Lagrangian dual method provides a more technically convenient and transparent solution to the optimal reinsurance design. To demonstrate the practicality of the proposed method, analytical solution is derived on a particular reinsurance model that involves minimizing Conditional Value at Risk (a special case of distortion function) and with the reinsurance premium being determined by the inverse-S shaped distortion principle.

ABDALLAH, ANAS; BOUCHER, JEAN-PHILIPPE; COSSETTE, HÉLÈNE. *Sarmanov family of multivariate distributions for bivariate dynamic claim counts model*. 120-133. To predict future claims, it is well-known that the most recent claims are more predictive than older ones. However, classic panel data models for claim counts, such as the multivariate negative binomial distribution, do not put any time weight on past claims. More complex models can be used to consider this property, but often need numerical procedures to estimate parameters. When we want to add a dependence between different claim count types, the task would be even more difficult to handle. In this paper, we propose a bivariate dynamic model for claim counts, where past claims experience of a given claim type is used to better predict the other type of claims. This new bivariate dynamic distribution for claim counts is based on random effects that come from the Sarmanov family of multivariate distributions. To obtain a proper dynamic distribution based on this kind of bivariate priors, an approximation of the posterior distribution of the random effects is proposed. The resulting model can be seen as an extension of the dynamic heterogeneity model described in Bolancé et al. (2007) [Bolancé, C., Denuit, M. Guillén, M., Lambert, P. (2007), Greatest accuracy credibility with dynamic heterogeneity: the Harvey-Fernandes model, *Belgian Actuarial Bulletin* 1: 14-18]. We apply this model to two samples of data from a major Canadian insurance company, where we show that the proposed model is one of the best models to adjust the data. We also show that the proposed model allows more flexibility in computing predictive premiums because closed-form expressions can be easily derived for the predictive distribution, the moments and the predictive moments.

ALIA, ISHAK; CHIGHOUB, FARID; SOHAIL, AYESHA. *A characterization of equilibrium strategies in continuous-time mean-variance problems for insurers*. 212-223. In this work, we study the equilibrium reinsurance/new business and investment strategy for mean-variance insurers with constant risk aversion. The insurers are allowed to purchase proportional reinsurance, acquire new business and invest in a financial market, where the surplus of the insurers is assumed to follow a jump-diffusion model and the financial market consists of one riskless asset and a multiple risky assets whose price processes are driven by Poisson random measures and independent Brownian motions. By using a version of the stochastic maximum principle approach, we characterize the open loop equilibrium strategies via a stochastic system which consists of a flow of forward-backward stochastic differential equations (FBSDEs in short) and an equilibrium condition. Then by decoupling the flow of FSBDEs, an explicit representation of an equilibrium solution is derived as well as its corresponding objective function value.

ATTIAS, ANNA; AREZZO, MARIA FELICE; PIANESE, AUGUSTO; VARGA, ZOLTAN. *A comparison of two legislative approaches to the pay-as-you-go pension system in terms of adequacy: the Italian case*. 203-211. The aim of our work is to evaluate a new legislative proposal of the Italian pension system due to Giuliano Cazzola e Tiziano Treu and to compare it with the system in force due to former Minister Elsa Fornero. The evaluation is made in terms of adequacy. We make use of a mathematical model which, under the hypothesis of demographic equilibrium, formalizes the legislative changes of the pay-as-you-go pension system. The model is tested using Italian demographic and socio-economic data. The pay-as-you-go pension system in force is notional defined contribution and has the huge drawback that the replacement rate (the ratio between the monthly pension and the last wage perceived by the worker) is very low. We compare the two pension systems evaluating the dynamics of the replacement rate.

BELLES-SAMPERA, JAUME; GUILLÉN, MONTSERRAT; SANTOLINO, MIGUEL. *What attitudes to risk underlie distortion risk measure choices?* 101-109. Understanding the attitude to risk implicit within a risk measure sheds some light on the way in which decision makers perceive losses. In this paper, a two-stage strategy is developed to characterize the underlying risk attitude involved in a risk evaluation, when executed by the family of distortion risk measures. First, we show that aggregation indicators defined for Choquet integrals provide information about the implicit global risk attitude of the agent. Second, an analysis of the distortion function offers a local description of the agent's stance on risk in relation to the occurrence of accumulated losses. Here, the concepts of absolute risk attitude and local risk attitude arise naturally. An example is provided to illustrate the usefulness of this strategy for characterizing risk attitudes in an insurance company.

BENUSAN, HARRY; EL KAROUI, NICOLE; LOISEL, STÉPHANE; SALHI, YAHIA. *Partial splitting of longevity and financial risks: The longevity nominal choosing swaptions.* 61-72. The previous attempts to launch liquid and standardized longevity derivatives in the market failed because banks do not seem to be ready to take longevity risk. Therefore, instead of trying to transfer longevity risk to investors, it could be interesting for financial institutions to propose interest rate hedges adapted to longevity portfolios, in the spirit of liability driven investments. In this paper, we introduce a new structured financial product: the so-called Longevity Nominal Chooser Swaption. Thanks to such a contract, insurers could keep pure longevity risk and transfer to financial markets a great part of interest rate risk underlying annuity portfolios. We use a population dynamics longevity model and a classical two-factor interest rate model to price this product. Numerical results show that the option offered to the insurer (in terms of choice of nominal) is not too expensive in many real-world cases. We also discuss the pros and the cons of the product and of our methodology.

CADENA, MEITNER; DENUIT, MICHEL M. *Semi-parametric accelerated hazard relational models with applications to mortality projections.* 1-16. In this paper, we propose new relational models linking some specific mortality experience to a reference life table. Compared to existing relational models which distort the forces of mortality, we work here on the age scale. Precisely, age is distorted making individuals younger or older before performing the computations with the reference life table. This is in line with standard actuarial practice, specifically with the so-called Rueff's adjustments. It is shown that the statistical inference can be conducted with the help of a suitably modified version of the standard IRWLS algorithm in a Poisson GLM/GAM setting. A dynamic version of this model is proposed to produce mortality projections. Numerical illustrations are performed on Belgian mortality statistics.

CUI, ZHENYU; NGUYEN, DUY. *Omega diffusion risk model with surplus-dependent tax and capital injections.* 150-161. In this paper, we propose and study an Omega risk model with a constant bankruptcy function, surplus-dependent tax payments and capital injections in a time-homogeneous diffusion setting. The surplus value process is both refracted (paying tax) at its running maximum and reflected (injecting capital) at a lower constant boundary. The new model incorporates practical features from the Omega risk model (Albrecher et al., 2011) [H. Albrecher, H. Gerber, E. Shiu (2011), The optimal dividend barrier in the Gamma-Omega model, European Actuarial Journal 1: 43-55], the risk model with tax (Albrecher and Hipp, 2007) [H. Albrecher, C. Hipp (2007), Lundberg's risk process with tax, Blätter der Deutsche Gesellschaft für Versicherungsmathematik 28(1): 13-28], and the risk model with capital injections (Albrecher and Ivanovs, 2014) [Albrecher, H., Ivanovs, J. (2014), Power identities for Lévy risk models under

taxation and capital injections, *Stochastic Systems* 4(1): 157-172]. The study of this new risk model is closely related to the Azéma-Yor process, which is a process refracted by its running maximum. We explicitly characterize the Laplace transform of the occupation time of an Azéma-Yor process below a constant level until the first passage time of another Azéma-Yor process or until an independent exponential time. We also consider the case when the process has a lower reflecting boundary. This result unifies and extends recent results of Li and Zhou (2013) [Li, B., Zhou, X. (2013), The joint Laplace transforms for diffusion occupation times, *Advanced Applied Probability* 45(4): 1049-1067] and Zhang (2015) [Zhang, H. (2015), Occupation time, draw-downs, and drawups for one-dimensional regular diffusion, *Advanced Applied Probability* 47(1): 210-230]. We explicitly characterize the Laplace transform of the time of bankruptcy in the Omega risk model with tax and capital injections up to eigen-functions, and determine the expected present value of tax payments until default. We also discuss a further extension to occupation functionals through stochastic time-change, which handles the case of a non-constant bankruptcy function. Finally we present examples using a Brownian motion with drift, and discuss the pricing of quantile options written on the Azéma-Yor process.

FERRIERO, A. *Solvency capital estimation, reserving cycle and ultimate risk*. 162-168. In this paper we propose a stochastic model for the evolution of the reserves for a non-life insurance run-off portfolio that captures the dynamic of the reserving cycle, which consists in years of prudent reserves releases followed by sudden reserves strengthening. In our model we assume that the relative loss developments over time follow a stochastic process with dependent increments, and that the consequently estimated reserves evolve as a stochastic process with discontinuous paths, which all together could be mathematically described as a geometric fractional Brownian motion with random jumps. The dependence between increments reflects the first phase of the reserving cycle, i.e. prudent reserve releases, whereas the second phase of the cycle is captured by the jumps. Remarkably in our model a jump in the reserves occurs after a period of systematic under-estimation of the losses, as happens in reality. As a product of our model we propose practical estimators for the Solvency Capital Requirement and the Risk Margin as defined in the European regulation (Solvency II, EIOPA-14/209, 2014), and analogously in the Swiss regulation (SST, FINMA, 2008), as functions of the ultimate risk.

FERSINI, PAOLA; MELISI, GIUSEPPE. *Stochastic model to evaluate the fair value of motor third-party liability under the direct reimbursement scheme and quantification of the capital requirement in a Solvency II perspective*. 27-44. As commonly known, to evaluate the claims reserve (otherwise known as the provision for outstanding claims), the loss adjuster uses as a first component the claims reserve given by the sum of the estimated provision for each outstanding claim (known as case reserve). Traditional statistical-actuarial methods are used to control and/or asseverate the evaluation and recent developments have tended to ensure that these enable an independent assessment of the claims reserve. In some European countries, a large subset of motor liability claims is managed within a direct reimbursement (DR) scheme. In Italy, the introduction of the direct compensation CARD system for third-party liability insurance has resulted in greater attention in the use of these traditional methods due to the heterogeneity of the data available for evaluations. This paper presents the results of a study undertaken to define a calculation method that, using the different assumptions that describe the evolution of settlement mechanisms, is able to quantify the claims reserve. The proposed methodology reduces the loss adjuster's discretion in applying statistical methods since all assumptions must be made explicit and can hence be monitored and controlled. Furthermore, a stress test can be performed on all the parameters that influence the settlement and thus the claims reserve. Finally, in a backtesting perspective, the

proposed methodology enables an ex-post analysis of actual cash flow deviations compared to expected values, identifying the variables that lead to these differences. In particular, a calculation method is presented that using the different assumptions describing the evolution of the settlement of different claim handling procedures (Non-Card, Card, Handler Forfait and Debtor Forfait) is able to quantify the claims reserve. Via simulations, future payments, the expected value of the claims reserve and some indicators of variability are also estimated. The numerical application allows comparing the results obtained with those deriving from the application of traditional statistical methods. The problem of aggregating the four claim handling procedures is dealt with by using copulas with the goal of building a single distribution of the aggregate claims reserve. Furthermore, in a Solvency II perspective, the capital requirement is determined against the reserve risk based on the internal model proposed and is compared with the standard formula proposed by EIOPA.

GUO, XU; LI, JINGYUAN. *Confidence band for expectation dependence with applications*. 141-149. Motivated by the applications of the concept of expectation dependence in economics and finance, we propose a method to construct uniform confidence band for expectation dependence. It is derived based on Hoeffding's inequality. Our proposed confidence band can be explicitly expressed and thus it is very easy to implement. Our method has applications to demand for a risky asset and first-order risk aversion problems. Simulations suggest our proposed confidence interval can control the coverage probabilities very well, and the average lengths are very short. Two empirical applications are presented to illustrate the usefulness of the constructed confidence band of expectation dependence.

KYNG, TIM; KONSTANDATOS, OTTO; BIENEK, T. *Valuation of employee stock options using the exercise multiple approach and life tables*. 17-26. Employee stock options (ESOs) are common in performance-based employee remuneration. Financial reporting standards such as IFRS2 and AASB2 require public corporations to report on the cost of providing ESOs, and mandate the incorporation of voluntary and involuntary early exercise. In this paper we extend the exercise multiple approach of Hull and White (2004) [J. Hull, A. White (2004), How to value employee stock options, *Financial Analysts Journal* 60(1): 114-119] and decompose the attrition unadjusted voluntary exercise ESO into a gap call option and two partial-time barrier options. We use exit probabilities obtained from empirically determined multiple decrement or life tables to model involuntary early exercise or forfeiture. We provide a new analytic valuation formula which expresses the ESO value in terms of a portfolio of exotic European bivariate power options and which correctly accounts for both voluntary exercise and employee attrition. Recent approaches seek to model employee attrition using a constant hazard rate. Our approach uses an empirically driven actuarial method for incorporating employee attrition in the valuation.

LI, XIAOHU; LI, CHEN. *On allocations to portfolios of assets with statistically dependent potential risk returns*. 178-186. This note studies how the allocation impacts on the expected potential return of the portfolio of risk assets with some new dependence structures characterized through the orthant probability of their potential returns. As applications, we revisit the financial risk model and actuarial default risk model, and study the dependence structure of potential risk returns and the utility functions such that in the optimal allocations the assets are arranged in ascending order. The main results complement some related ones of Cheung and Yang (2004) [K.C. Cheung, H. Yang (2004), Ordering optimal proportions in the asset allocation problem with dependent default risks, *Insurance Mathematics and Economics* 35: 595-609] and Chen and Hu (2008) [Chen, Z., Hu, T. (2008), Asset proportions in optimal portfolios with dependent default risks, *Insurance Mathematics and Economics* 43: 223-226].

LI, YUNXIAN; TANG, NIANSHENG. *Bayesian approaches for analyzing earthquake catastrophic risk*. 110-119. Extreme value theory has been widely used in analyzing catastrophic risk. The theory mentioned that the generalized Pareto distribution (GPD) could be used to estimate the limiting distribution of the excess value over a certain threshold; thus the tail behaviors are analyzed. However, the central behavior is important because it may affect the estimation of model parameters in GPD, and the evaluation of catastrophic insurance premiums also depends on the central behavior. This paper proposes four mixture models to model earthquake catastrophic loss and proposes Bayesian approaches to estimate the unknown parameters and the threshold in these mixture models. MCMC methods are used to calculate the Bayesian estimates of model parameters, and deviance information criterion values are obtained for model comparison. The earthquake loss of Yunnan province is analyzed to illustrate the proposed methods. Results show that the estimation of the threshold and the shape and scale of GPD are quite different. Value-at-risk and expected shortfall for the proposed mixture models are calculated under different confidence levels.

LU, ZHIYI; MENG, LILI; WANG, YUJIN; SHEN, QINGJIE. *Optimal reinsurance under VaR and TVaR risk measures in the presence of reinsurer's risk limit*. 92-100. In most studies on optimal reinsurance, little attention has been paid to controlling the reinsurer's risk. However, real-world insurance markets always place a limit on coverage, otherwise the insurer will be subjected to under a heavy financial burden when the insured suffers a large unexpected covered loss. In this paper, we revisit the optimal reinsurance problem under the optimality criteria of VaR and TVaR risk measures when the constraints for the reinsurer's risk exposure are presented. Two types of constraints are considered that have been proposed by Cummins and Mahul (2004) [Cummins, J.D., Mahul, O. (2004), The demand for insurance with an upper limit on coverage, *Journal of Risk and Insurance* 71(2): 253-264] and Zhou et al. (2010) [Zhou, C., Wu, W., Wu, C. (2010), Optimal insurance in the presence of insurer's loss limit, *Insurance Mathematics & Economics* 46(2): 300-307], respectively. It is shown that two-layer reinsurance is always the optimal reinsurance policy under both VaR and TVaR risk measures and under both types of constraints. This implies that the two-layer reinsurance policy is more robust. Furthermore, the optimal quantity of ceded risk depends on the confidence level, the safety loading and the tolerance level, as well as on the relation between them.

PUN, CHI SENG; WONG, HOI YING. *Robust non-zero-sum stochastic differential reinsurance game*. 169-177. This paper considers the non-zero-sum stochastic differential game problem between two ambiguity-averse insurers (AAIs) who encounter model uncertainty and seek the optimal reinsurance decision under relative performance concerns. Each AAI manages her own risks by purchasing reinsurance with the objective of maximizing the expected utility of her relative terminal surplus with respect to that of her counterparty. The two AAIs' decisions influence each other through the insurers' relative performance concerns and the correlation between their surplus processes. We establish a general framework of Nash equilibrium for the associated non-zero-sum game with model uncertainty. For the representative case of exponential utilities, we solve the equilibrium strategies explicitly. Numerical studies are conducted to draw economic interpretations.

RISK, J; LUDKOVSKI, M. *Statistical emulators for pricing and hedging longevity risk products*. 45-60. We propose the use of statistical emulators for the purpose of analyzing mortality-linked contracts in stochastic mortality models. Such models typically require (nested) evaluation of expected values of nonlinear functionals of multi-dimensional stochastic processes. Except in the simplest cases, no closed-form expressions are available, necessitating numerical approximation. To complement various analytic approximations, we advocate the use of modern statistical tools

from machine learning to generate a flexible, non-parametric surrogate for the true mappings. This method allows performance guarantees regarding approximation accuracy and removes the need for nested simulation. We illustrate our approach with case studies involving (i) a Lee-Carter model with mortality shocks; (ii) index-based static hedging with longevity basis risk; (iii) a Cairns-Blake-Dowd stochastic survival probability model; (iv) variable annuities under stochastic interest rate and mortality.

SAMANTHI, RANADEERA GAMAGE MADHUKA; WEI, WEI; BRAZAUSKAS, VYTARAS.

Ordering Gini indexes of multivariate elliptical risks. 84-91. Gini index is a well-known tool in economics that is often used for measuring income inequality. In insurance, the index and its modifications have been used to compare the riskiness of portfolios, to order reinsurance contracts, and to summarize insurance scores (relativities). In this paper, we establish several stochastic orders between the Gini indexes of multivariate elliptical risks with the same marginals but different dependence structures. This work is motivated by the applied studies of Brazauskas et al. (2007) [Brazauskas, V., Jones, B.L., Puri, M.L., Zitikis, R. (2007), Nested LL-statistics and their use in comparing the riskiness of portfolios, Scandinavian Actuarial Journal 2007(3): 162-179] and Samanthi et al. (2015) [Samanthi, R.G.M., Wei, W., Brazauskas, V., 2015. Comparing the riskiness of dependent portfolios via nested LL-statistics, submitted for publication], who employed the Gini index to compare the riskiness of insurance portfolios. Based on extensive Monte Carlo simulations, these authors have found that the power function of the associated hypothesis test increases as portfolios become more positively correlated. The comparison of the Gini indexes (of empirically estimated risk measures) presented in this paper provides a theoretical explanation to this statistical phenomenon. Moreover, it enriches the studies of the problem of central concentration of elliptical distributions and generalizes the pd-1 order proposed by Shaked and Tong (1985) [Shaked, M., Tong, Y.L. (1985), Some partial orderings of exchangeable random variables by positive dependence, Journal of Multivariate Analysis 17: 333-349].

SIBURG, KARL FRIEDRICH; STEHLING, KATHARINA; STOIMENOV, PAVEL A; WEIß, GREGOR N F.

An order of asymmetry in copulas, and implications for risk management. 241-247. We study symmetry properties of bivariate copulas. For this, we introduce an order of asymmetry, as well as measures of asymmetry which are monotone in that order. In an empirical study, we illustrate that asymmetric dependence structures do indeed occur in financial market data and discuss its relevance for financial risk management.

SORDO, MIGUEL A. *A multivariate extension of the increasing convex order to compare risks.*

224-230. In this paper, we propose a generalization of the increasing convex order to the multivariate setting to compare vectors of risks that accounts for both the marginal impacts and the dependence structures of the vectors. This generalization is suitable for comparing vectors with heterogeneous components and extends some well-known properties of the univariate increasing convex order. For example, comparisons of vectors with the same copula can be characterized in terms of the multivariate tail conditional expectations introduced by Cousin and Di Bernardino (2014) [Cousin, A., Bernardino, E. Di (2014), On multivariate extensions of value-at-risk, Journal of Multivariate Analysis 119: 32-46]. Moreover, if the copula reflects a particular positive dependence structure, the order among the vectors can be easily verified simply by checking the univariate increasing convex order of the marginals.

TAN, CHONG IT. *Varying transition rules in bonus-malus systems: From rules specification to*

determination of optimal relativities. 134-140. In this paper, we extend the proposed idea of

level-varying transition rules in bonus-malus systems onto risk-varying rules and combine both these ideas to formulate the generalization of varying transition rules. Moreover, we generalize the analytical formulae for the determination of optimal relativities under these rules. We find that the risk-varying transition rules are the most effective among the different specifications of transition rules. Our numerical results also indicate that the resulting optimal relativities under the general-varying rules are higher than those of under the risk-varying rules partly due to the differences of the transitions imposed by the rules.

WANG, GUANQING; WANG, GUOJING; YANG, HAILIANG. *On a multi-dimensional risk model with regime switching*. 73-83. We consider an insurer with $n(n \geq 2)$ classes of insurance business. The surplus process for each class of insurance business is assumed to follow a compound Cox risk process. Assume that n surplus processes are correlated with thinning dependence and regime switching. By summing up the n surplus processes we obtain a correlated risk process. Upper bounds for the ruin probability under certain assumptions are derived. The joint ruin probability for n classes of insurance business, the distribution of the number of the ruined business classes in a finite time interval and the Laplace transform of the ruin time of the correlated risk process are investigated. Some closed form results are obtained. Numerical examples are presented to explain how the collection of insurance risk increases the solvency of an insurer.

WANG, XING; PENG, LIANG. *Inference for intermediate Haezendonck-Goovaerts risk measure*. 231-240. Recently Haezendonck-Goovaerts (H-G) risk measure has received much attention in actuarial science. Nonparametric inference has been studied by Ahn and Shyamalkumar (2014) [Ahn, J.Y., Shyamalkumar, N.D. (2014), Asymptotic theory for the empirical Haezendonck-Goovaerts risk measure, *Insurance: Mathematics and Economics* 55: 78-90] and Peng et al. (2015) [Peng, L., Wang, X., Zheng, Y. (2015), Empirical likelihood inference for Haezendonck-Goovaerts risk measure, *European Actuarial Journal* 5: 427-445] when the risk measure is defined at a fixed level. In risk management, the level is usually set to be quite near one by regulators. Therefore, especially when the sample size is not large enough, it is useful to treat the level as a function of the sample size, which diverges to one as the sample size goes to infinity. In this paper, we extend the results in Peng et al. (2015) from a fixed level to an intermediate level. Although the proposed maximum empirical likelihood estimator for the H-G risk measure has a different limit for a fixed level and an intermediate level, the proposed empirical likelihood method indeed gives a unified interval estimation for both cases. A simulation study is conducted to examine the finite sample performance of the proposed method.

ZHOU, ZHOU; XIAO, HELU; YIN, JIALING; ZENG, XIMEI; LIN, LING. *Pre-commitment vs. time-consistent strategies for the generalized multi-period portfolio optimization with stochastic cash flows*. 187-202. In this paper, we propose a multi-period portfolio optimization model with stochastic cash flows. Under the mean-variance preference, we derive the pre-commitment and time-consistent investment strategies by applying the embedding scheme and backward induction approach, respectively. We show that the time-consistent strategy is identical to the optimal open-loop strategy. Also, under the exponential utility preference, we develop the optimal strategy for multi-period investment, which is time-consistent. We show that the above two time-consistent strategies are equivalent in some cases. We compare the pre-commitment and time-consistent strategies under different situations with some numerical simulations. The results indicate that the time-consistent strategy is more stable and secure than pre-commitment strategy under the generalized mean-variance criterion.

ANGOSHTARI, BAHMAN; BAYRAKTAR, ERHAN; YOUNG, VIRGINIA R. *Minimizing the probability of lifetime drawdown under constant consumption*. 210-223. We assume that an individual invests in a financial market with one riskless and one risky asset, with the latter's price following geometric Brownian motion as in the Black–Scholes model. Under a constant rate of consumption, we find the optimal investment strategy for the individual who wishes to minimize the probability that her wealth drops below some fixed proportion of her maximum wealth to date, the so-called probability of lifetime drawdown. If maximum wealth is less than a particular value, m^*m^* , then the individual optimally invests in such a way that maximum wealth never increases above its current value. By contrast, if maximum wealth is greater than m^*m^* but less than the safe level, then the individual optimally allows the maximum to increase to the safe level.

BADESCU, ANDREI L; LIN, SHELDON; TANG, DAMENG. *A marked Cox model for the number of IBNR claims: theory*. 29-37. Incurred but not reported (IBNR) loss reserving is an important issue for Property & Casualty (P&C) insurers. To calculate IBNR reserve, one needs to model claim arrivals and then predict IBNR claims. However, factors such as temporal dependence among claim arrivals and environmental variation are often not incorporated in many of the current loss reserving models, which may greatly affect the accuracy of IBNR predictions. In this paper, we propose to model the claim arrival process together with its reporting delays as a marked Cox process. Our model is versatile in modeling temporal dependence, allowing also for natural interpretations. This paper focuses mainly on the theoretical aspects of the proposed model. We show that the associated reported claim process and IBNR claim process are both marked Cox processes with easily convertible intensity functions and marking distributions. The proposed model can also account for fluctuations in the exposure. By an order statistics property, we show that the corresponding discretely observed process preserves all the information about the claim arrivals. Finally, we derive closed-form expressions for both the autocorrelation function (ACF) and the distributions of the numbers of reported claims and IBNR claims. Model estimation and its applications are considered in a subsequent paper, Badescu et al. (2015b) [Badescu, A.L., Lin, X.S., Tang, D. (2015). A marked Cox model for the number of IBNR claims: estimation and application. Available at <http://ssrn.com/abstract=2747223>].

COHEN, ASAF; YOUNG, VIRGINIA R. *Minimizing lifetime poverty with a penalty for bankruptcy*. 156-167. We provide investment advice for an individual who wishes to minimize her lifetime poverty, with a penalty for bankruptcy or ruin. We measure poverty via a non-negative, non-increasing function of (running) wealth. Thus, the lower wealth falls and the longer wealth stays low, the greater the penalty. This paper generalizes the problems of minimizing the probability of lifetime ruin and minimizing expected lifetime occupation, with the poverty function serving as a bridge between the two. To illustrate our model, we compute the optimal investment strategies for a specific poverty function and two consumption functions, and we prove some interesting properties of those investment strategies.

DJEHICHE, BOUALEM; LÖFDAHL, BJÖRN. *Nonlinear reserving in life insurance: aggregation and mean-field approximation*. 1-13. We suggest a unified approach to claims reserving for life insurance policies with reserve-dependent payments driven by multi-state Markov chains. The associated prospective reserve is formulated as a recursive utility function using the framework of

backward stochastic differential equations (BSDE). We show that the prospective reserve satisfies a nonlinear Thiele equation for Markovian BSDEs when the driver is a deterministic function of the reserve and the underlying Markov chain. Aggregation of prospective reserves for large and homogeneous insurance portfolios is considered through mean-field approximations. We show that the corresponding prospective reserve satisfies a BSDE of mean-field type and derive the associated nonlinear Thiele equation.

FENG, RUNHUAN; SHIMIZU, YASUTAKA. *Applications of central limit theorems for equity-linked insurance*. 138-148. In both the past literature and industrial practice, it was often implicitly used without any justification that the classical strong law of large numbers applies to the modeling of equity-linked insurance. However, as all policyholders' benefits are linked to common equity indices or funds, the classical assumption of independent claims is clearly inappropriate for equity-linked insurance. In other words, the strong law of large numbers fails to apply in the classical sense. In this paper, we investigate this fundamental question regarding the validity of strong laws of large numbers for equity-linked insurance. As a result, extensions of classical laws of large numbers and central limit theorem are presented, which are shown to apply to a great variety of equity-linked insurance products.

FURMAN, EDWARD; KUZNETSOV, ALEXEY; SU, JIANXI; ZITIKIS, RICARDAS. *Tail dependence of the Gaussian copula revisited*. 97-103. Tail dependence refers to clustering of extreme events. In the context of financial risk management, the clustering of high-severity risks has a devastating effect on the well-being of firms and is thus of pivotal importance in risk analysis. When it comes to quantifying the extent of tail dependence, it is generally agreed that measures of tail dependence must be independent of the marginal distributions of the risks but rather solely copula-dependent. Indeed, all classical measures of tail dependence are such, but they investigate the amount of tail dependence along the main diagonal of copulas, which has often little in common with the concentration of extremes in the copulas' domain of definition. In this paper we urge that the classical measures of tail dependence may underestimate the level of tail dependence in copulas. For the Gaussian copula, however, we prove that the classical measures are maximal. The implication of the result is two-fold: On the one hand, it means that in the Gaussian case, the (weak) measures of tail dependence that have been reported and used are of utmost prudence, which must be a reassuring news for practitioners. On the other hand, it further encourages substitution of the Gaussian copula with other copulas that are more tail dependent.

GODÍNEZ OLIVARES, HUMBERTO; DEL CARMEN BOADO-PENAS, MARIA; HABERMAN, STEVEN. *Optimal strategies for pay-as-you-go pension finance: a sustainability framework*. 117-126. The aim of this paper is to design an automatic balancing mechanism to restore the sustainability of a pay-as-you-go (PAYG) pension system based on changes in its main variables, such as the contribution rate, normal retirement age and indexation of pensions. Using nonlinear optimisation, this mechanism, identifies and applies an optimal path of these variables to a PAYG system in the long run and absorbs fluctuations in longevity, fertility rates, salary growth or any other events in a pension system.

GUAN, GUOHUI; LIANG, ZONGXIA. *Optimal management of DC pension plan under loss aversion and Value-at-Risk constraints*. 224-237. This paper studies the risk management in a defined contribution (DC)pension plan. The financial market consists of cash, bond and stock. The interest rate in our model is assumed to follow an Ornstein-Uhlenbeck process while the contribution rate follows a geometric Brownian Motion. Thus, the pension manager has to hedge

the risks of interest rate, stock and contribution rate. Different from most works in DC pension plan, the pension manager has to obtain the optimal allocations under loss aversion and Value-at-Risk (VaR) constraints. The loss aversion pension manager is sensitive to losses while the VaR pension manager has to ensure the quality of wealth at retirement. Since these problems are not standard concave optimization problems, martingale method is applied to derive the optimal investment strategies. Explicit solutions are obtained under these two optimization criterions. Moreover, sensitivity analysis is presented in the end to show the economic behaviors under these two criteria.

KONSTANTINIDES, DIMITRIOS G; LI, JINZHU. *Asymptotic ruin probabilities for a multi-dimensional renewal risk model with multivariate regularly varying claims*. 38-44. This paper studies a continuous-time multidimensional risk model with constant force of interest and dependence structures among random factors involved. The model allows a general dependence among the claim-number processes from different insurance businesses. Moreover, we utilize the framework of multivariate regular variation to describe the dependence and heavy-tailed nature of the claim sizes. Some precise asymptotic expansions are derived for both finite-time and infinite-time ruin probabilities.

KOUTRAS, VASILEIOS M; KOUTRAS, MARKOS V; YALCIN, FEMIN. *A simple compound scan statistic useful for modeling insurance and risk management problem*. 202-209. In the present work we study the distribution of a random sum of random variables which is related to a binary scan statistic for Markov dependent trials. The motivation of the model studied herein stems from several areas of applied science such as actuarial science, financial risk management, quality control and reliability, educational psychology, engineering, etc. Let us consider a sequence of binary success/failure trials and denote by T_k the waiting time for the first occurrence of two successes separated by at most k failures, where $k \geq 0$ is any integer. Let also $Y_1, Y_2, \dots, Y_1, Y_2, \dots$ be a sequence of independent and identically distributed (i.i.d) discrete random variables, independent of T_k . In the present article we develop some results for the distribution of the compound random variable $S_k = \sum_{t=1}^{T_k} Y_t$ and illustrate how these results can be profitably used to study models pertaining to actuarial science and financial risk management practice.

LECCADITO, ARTURO; PALETTA, TOMMASO; TUNARU, RADU. *Pricing and hedging basket options with exact moment matching*. 59-69. Theoretical models applied to option pricing should take into account the empirical characteristics of financial time series. In this paper, we show how to price basket options when the underlying asset prices follow a displaced log-normal process with jumps, capable of accommodating negative skewness and excess kurtosis. Our technique involves Hermite polynomial expansion that can match exactly the first m moments of the model-implied basket return. This method is shown to provide superior results for basket options not only with respect to pricing but also for hedging.

LIANG, ZONGXIA; SHENG, WENLONG. *Valuing inflation-linked death benefits under a stochastic volatility framework*. 45-58. In this paper we construct a framework to price the inflation-linked derivatives with the stochastic inflation rate, the stochastic interest rate, and stochastic risky assets with stochastic volatility. Because of the popularity of the guaranteed minimum death benefit (GMDB) in insurance market, we mainly study two types of GMDBs: the inflation guarantee and the combination guarantee. We consider the guaranteed minimum death benefit as an European option with a random maturity date, the closed-form pricing formulas for the GMDBs are derived by Fourier-based method. Moreover, we give an elaborate sensitivity analysis

to explain economical behaviors of our models. The numerical results show that the death benefit of inflation guarantee is slightly overpriced in constant volatility of stock situation.

NAJAFABADI, AMIR T PAYANDEH; BAZAZ, ALI PANAHI. *An optimal co-reinsurance strategy*. 149-155. This article considers a co-reinsurance strategy that (1) protects insurance companies against catastrophic risks; (2) enables insurers to gather sufficient information about the different risk attitudes of reinsurers and diversify their reinsured risks; (3) enables insurers to create better risk-sharing profiles by balancing the risk tolerances of reinsurers; (4) has the benefit of allowing reinsurers to accumulate experience with risks with which they are unfamiliar; (5) reduces the overall direct cost of a reinsurance contract; (6) allows a government to back some insurance products, such as the terrorism insurance programs that were established in many countries after the September 11th terrorist attacks; and (7) reflects the practical reinsurance industry of some countries, such as Iran. Such a co-reinsurance strategy can be fully determined by estimating its parameters whenever three optimal criteria are satisfied and prior information about the unknown parameters is available. Two simulation-based studies have been conducted to demonstrate (1) the practical applications of our findings and (2) the possible impact of any type of dependency between the co-reinsurance's parameters and the evaluated optimal co-reinsurance strategy.

PENG, XINGCHUN; WANG, WENYUAN. *Optimal investment and risk control for an insurer under inside information*. 104-116. This paper is devoted to the study of the optimal investment and risk control strategy for an insurer who has some inside information on the financial market and the insurance business. The insurer's risk process and the risky asset process in the financial market are assumed to be very general jump diffusion processes. The two processes are supposed to be correlated. Under the criterion of logarithmic utility maximization of the terminal wealth, we solve our problem by using forward integral approach. Some interesting particular cases are studied in which the explicit expressions of the optimal strategy are derived by using enlargement of filtration techniques.

PLATANAKIS, EMMANOUIL; SUTCLIFFE, CHARLES. *Pension scheme redesign and wealth redistribution between the members and sponsor: the USS rule change in October 2011*. 14-28. The redesign of defined benefit pension schemes usually results in a substantial redistribution of wealth between age cohorts of members, pensioners, and the sponsor. This is the first study to quantify the redistributive effects of a rule change by a real world scheme (the Universities Superannuation Scheme, USS) where the sponsor underwrites the pension promise. In October 2011 USS closed its final salary scheme to new members, opened a career average revalued earnings (CARE) section, and moved to 'cap and share' contribution rates. We find that the pre-October 2011 scheme was not viable in the long run, while the post-October 2011 scheme is probably viable in the long run, but faces medium term problems. In October 2011 future members of USS lost 65% of their pension wealth (or roughly £100,000 per head), equivalent to a reduction of roughly 11% in their total compensation, while those aged over 57 years lost almost nothing. The riskiness of the pension wealth of future members increased by a third, while the riskiness of the present value of the sponsor's future contributions reduced by 10%. Finally, the sponsor's wealth increased by about £32.5 billion, equivalent to a reduction of 26% in their pension costs.

SCHINZINGER, EDO; DENUIT, MICHEL M; CHRISTIANSEN, MARCUS C. *A multivariate evolutionary credibility model for mortality improvement rates*. 70-81. The present paper

proposes an evolutionary credibility model that describes the joint dynamics of mortality through time in several populations. Instead of modeling the mortality rate levels, the time series of population-specific mortality rate changes, or mortality improvement rates are considered and expressed in terms of correlated time factors, up to an error term. Dynamic random effects ensure the necessary smoothing across time, as well as the learning effect. They also serve to stabilize successive mortality projection outputs, avoiding dramatic changes from one year to the next. Statistical inference is based on maximum likelihood, properly recognizing the random, hidden nature of underlying time factors. Empirical illustrations demonstrate the practical interest of the approach proposed in the present paper.

SCHOLZ, MICHAEL; SPERLICH, STEFAN; NIELSEN JENS PERCH. *Nonparametric long term prediction of stock returns with generated bond yields*. 82-96. Recent empirical approaches in forecasting equity returns or premiums found that dynamic interactions among the stock and bond are relevant for long term pension products. Automatic procedures to upgrade or downgrade risk exposure could potentially improve long term performance for such products. The risk and return of bonds is more easy to predict than the risk and return of stocks. This and the well known stock-bond correlation motivates the inclusion of the current bond yield in a model for the prediction of excess stock returns. Here, we take the actuarial long term view using yearly data, and focus on nonlinear relationships between a set of covariates. We employ fully nonparametric models and apply for estimation a local-linear kernel smoother. Since the current bond yield is not known, it is predicted in a prior step. The structure imposed this way in the final estimation process helps to circumvent the curse of dimensionality and reduces bias in the estimation of excess stock returns. Our validated stock prediction results show that predicted bond returns improve stock prediction significantly.

SHEN, YANG; SHERRIS, MICHAEL; ZIVEYI, JONATHAN. *Valuation of guaranteed minimum maturity benefits in variable annuities with surrender options*. 127-137. We present a numerical approach to the pricing of guaranteed minimum maturity benefits embedded in variable annuity contracts in the case where the guarantees can be surrendered at any time prior to maturity that improves on current approaches. Surrender charges are important in practice and are imposed as a way of discouraging early termination of variable annuity contracts. We formulate the valuation framework and focus on the surrender option as an American put option pricing problem and derive the corresponding pricing partial differential equation by using hedging arguments and Itô's Lemma. Given the underlying stochastic evolution of the fund, we also present the associated transition density partial differential equation allowing us to develop solutions. An explicit integral expression for the pricing partial differential equation is then presented with the aid of Duhamel's principle. Our analysis is relevant to risk management applications since we derive an expression of the delta for the sensitivity analysis of the guarantee fees with respect to changes in the underlying fund value. We provide algorithms for implementing the integral expressions for the price, the corresponding early exercise boundary and the delta of the surrender option. We quantify and assess the sensitivity of the prices, early exercise boundaries and deltas to changes in the underlying variables including an analysis of the fair insurance fees.

SIU, TAK KUEN. *A self-exciting threshold jump-diffusion model for option valuation*. 168-193.

A self-exciting threshold jump-diffusion model for option valuation is studied. This model can incorporate regime switches without introducing an exogenous stochastic factor process. A generalized version of the Esscher transform is used to select a pricing kernel. The valuation of both the European and American contingent claims is considered. A piecewise linear

partial-differential-integral equation governing a price of a standard European contingent claim is derived. For an American contingent claim, a formula decomposing a price of the American claim into the sum of its European counterpart and the early exercise premium is provided. An approximate solution to the early exercise premium based on the quadratic approximation technique is derived for a particular case where the jump component is absent. Numerical results for both European and American options are presented for the case without jumps.

TURSUNALIEVA, AINURA; SILVAPULLE, PARAM. *Nonparametric estimation of operational value-at-risk (OpVaR)* 194-201. This paper introduces nonparametric methods for estimating 99.9% operational value-at-risk (OpVaR) and its confidence interval (CI), and demonstrates their applications to US business losses. An attractive feature of these new methods is that there is no need to estimate either the entire heavy-tailed loss distribution or the tail region of the distribution. Furthermore, we provide algorithms that facilitate applied researchers and practitioners in risk management area to implement the sophisticated empirical likelihood ratio (ELR) based methodologies to construct the CI of the true underlying 99.9% OpVaR. In a simulation study, we find that the weighted ELR (WELR) CI estimator is more reliable than the ELR CI estimator. The empirical results show that the nonparametric OpVaR estimates are consistently larger than those of other comparable methods, which provide adequate regulatory capitals, particularly during crises. The findings have implications for regulators, and effective and efficient risk financing.

WANG, TING; YOUNG, VIRGINIA R. *Hedging pure endowments with mortality derivatives.* 238-255. In recent years, a market for mortality derivatives began developing as a way to handle systematic mortality risk, which is inherent in life insurance and annuity contracts. Systematic mortality risk is due to the uncertain development of future mortality intensities, or hazard rates. In this paper, we develop a theory for pricing pure endowments when hedging with a mortality forward is allowed. The hazard rate associated with the pure endowment and the reference hazard rate for the mortality forward are correlated and are modeled by diffusion processes. We price the pure endowment by assuming that the issuing company hedges its contract with the mortality forward and requires compensation for the unhedgeable part of the mortality risk in the form of a pre-specified instantaneous Sharpe ratio. The major result of this paper is that the value per contract solves a linear partial differential equation as the number of contracts approaches infinity. One can represent the limiting price as an expectation under an equivalent martingale measure. Another important result is that hedging with the mortality forward may raise or lower the price of this pure endowment comparing to its price without hedging, as determined in Bayraktar et al. (2009) [Bayraktar, E., Milevsky, M.A., Promislow, S.D., Young, V.R. (2009), Valuation of mortality risk via the instantaneous sharpe ratio: Applications to life annuities, *Journal of Economics and Dynamics Control* 33(3): 676-691]. The market price of the reference mortality risk and the correlation between the two portfolios jointly determine the cost of hedging. We demonstrate our results using numerical examples.

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BROWN, JEFFREY R; KAPTEYN, ARIE; MITCHELL, OLIVIA S. *Framing and claiming: how information-framing affects expected social security claiming behavior.* 139-162. This article provides evidence that Social Security benefit claiming decisions are strongly affected by framing and are thus inconsistent with expected utility theory. Using a randomized experiment that controls for both observable and unobservable differences across individuals, we find that the use of a “breakeven analysis” encourages early claiming. Respondents are more likely to delay when later claiming is framed as a gain, and the claiming age is anchored at older ages. Additionally, the financially less literate, individuals with credit card debt, and those with lower earnings are more influenced by framing than others.

BUNDORF, M KATE. *Consumer-directed health plans: a review of the evidence.* 9-41. The number of people enrolled in consumer-directed health plans (CDHPs) has increased dramatically over the last decade. We review the empirical literature on the effects of CDHPs, which is based on the experience of these plans in the employer-sponsored market. Studies indicate that CDHPs reduce health care spending by approximately 5–15 percent relative to similar plans with lower deductibles and without spending accounts. Spending reductions are concentrated among healthier enrollees and are driven by reductions in the use of outpatient services and pharmaceuticals. There is little evidence on whether they reduce the use of low-value services.

HANSEN, JAN V; JACOBSEN, RASMUS H; LAU, MORTEN I. *Willingness to pay for insurance in Denmark.* 49-76. We estimate how much Danish households are willing to pay for auto, home, and house insurance. We use a unique combination of claims data from a large Danish insurance company, measures of individual risk attitudes and discount rates from a field experiment with a representative sample of the adult Danish population, and information on household income and wealth from registers at Statistics Denmark. The results show that the willingness to pay is marginally higher than the actuarially fair value under expected utility theory, but significantly higher under rank-dependent utility theory, and up to 600 percent higher than the actuarially fair value.

HARRISON, GLENN W; NG, JIA MIN. *Evaluating the expected welfare gain from insurance.* 91-120. Economic theory tells us how to evaluate the expected welfare gain from insurance products on offer to individuals. If we know the risk preferences of the individual, and subjective beliefs about loss contingencies and likelihood of payout, there is a certainty equivalent of the risky insurance policy that can be compared to the certain insurance premium. This simple logic extends to nonstandard models of risk preferences, such as those in which individuals exhibit “optimism” or “pessimism” about loss contingencies in their evaluation of the risky insurance policy. We illustrate the application of these basic ideas about the welfare evaluation of insurance policies in a controlled laboratory experiment. We estimate the risk preferences of individuals from one task, and separately present the individual with a number of insurance policies in which loss contingencies are objective. We then estimate the expected consumer surplus gained or foregone from observed take-up decisions. There is striking evidence of foregone expected consumer surplus from incorrect take-up decisions. Indeed, the metric of take-up itself, widely used in welfare evaluations of insurance products, provides a qualitatively incorrect guide to the expected welfare effects of insurance.

HUANG, RACHEL J; MUERMANN, ALEXANDER; TZENG, LARRY Y. *Hidden regret in insurance markets*. 181-216. We examine insurance markets with two-dimensional asymmetric information on risk type and on preferences related to regret. In contrast to Rothschild and Stiglitz (1976), the equilibrium can be efficient; that is, it can coincide with the equilibrium under full information. Furthermore, we show that pooling, semipooling, and separating equilibria can exist. Specifically, there exist separating equilibria that predict a positive correlation between the level of insurance coverage and risk type, as in the standard economic models of adverse selection, but there also exist separating equilibria that predict a negative correlation between the level of insurance coverage and risk type. Since optimal choice of regretful customers depends on foregone alternatives, the equilibrium includes a contract that is offered but not purchased.

JASPERSEN, JOHANNES G. *Hypothetical surveys and experimental studies of insurance demand: a review*. 217-255. We offer a structured literature survey of experimental studies involving insurance demand choices and their experimental methodology. With this, we aim to fulfill two goals. First, we want to give an overview of the status of the literature as is. Second, the overview of the methodology provides researchers with an idea of how insurance demand experiments can be designed and what the advantages and disadvantages of the different design aspects are. We thus offer a resource for the design of future experiments.

KNOLLER, CHRISTIAN. *Multiple reference points and the demand for principal-protected life annuities: an experimental analysis*. 163-179. We conducted an experiment in which participants were confronted with an experimental annuitization decision. Previous research has argued in favor of the hypothesis that a combination of mental accounting and prospect theory can explain why annuities containing a capital guarantee are preferred to standard annuities. However, from this perspective people would not annuitize their assets at all, but rather invest the money in a risk-free alternative. Recent research has also suggested a “cushion effect.” When all possible outcomes of two options are above a certain goal, this goal serves as a cushion in case of unfavorable outcomes. Hence, individuals might have a higher propensity to exhibit risk-seeking behavior. We find that individuals were indeed more willing to choose the annuity option if it contained a capital guarantee and that individuals using this guarantee as a cushion were even more willing to choose the annuity. Thus, the cushion effect can partially explain the high demand for guarantee features in annuity contracts.

LIU, YANYAN; MYERS, ROBERT J. *The dynamics of microinsurance demand in developing countries under liquidity constraints and insurer default risk*. 121-138. We study the dynamics of microinsurance demand by risk-averse agents who can borrow and lend subject to a liquidity constraint, and also perceive a risk of insurer default. Liquidity constraints and perceived insurer default both reduce the demand for insurance, possibly leading to nonparticipation. We also evaluate an alternative insurance design that allows agents to delay premium payment until the end of the insured period when income is realized and indemnities are paid. We show this alternative design increases insurance take-up by relaxing the liquidity constraint and ameliorating concerns about insurer default. We also investigate the value of delayed premium payment, and the importance of the associated problem of renegeing if the insured event does not occur, under a range of conditions.

SCHMIDT, ULRICH. *Insurance demand under prospect theory: a graphical analysis*. 77-89. This article analyzes insurance demand under prospect theory in a simple model with two states of the world and fair insurance contracts. We argue that two different reference points are reasonable in

this framework, state-dependent initial wealth or final wealth after buying full insurance. Applying the value function of Tversky and Kahneman (1992), we find that for both reference points subjects will either demand full insurance or no insurance at all. Moreover, this decision depends on the probability of the loss: the higher the probability of the loss, the higher is the propensity to take up insurance. This result can explain empirical evidence that has shown that people are unwilling to insure rare losses at subsidized premiums and at the same time take up insurance for moderate risks at highly loaded premiums.

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BIFFIS, ENRICO; BLAKE, DAVID; PITOTTI, LORENZO; SUN, ARIEL. *The cost of counterparty risk and collateralization in longevity swaps*. 387-419. Derivative longevity risk solutions, such as bespoke and indexed longevity swaps, allow pension schemes, and annuity providers to swap out longevity risk, but introduce counterparty credit risk, which can be mitigated if not fully eliminated by collateralization. We examine the impact of bilateral default risk and collateral rules on the marking to market of longevity swaps, and show how longevity swap rates must be determined endogenously from the collateral flows associated with the marking-to-market procedure. For typical interest rate and mortality parameters, we find that the impact of collateralization is modest in the presence of symmetric default risk, but more pronounced when default risk and/or collateral rules are asymmetric. Our results suggest that the overall cost of collateralization is comparable with, and often much smaller than, that found in the interest rate swaps market, which may then provide the appropriate reference framework for the credit enhancement of both indemnity-based and indexed longevity risk solutions.

CHRISTIANSEN, MARCUS C; ELING, MARTIN; SCHMIDT, JAN-PHILIPP; ZIRKELBACH, LORENZ. *Who is changing health insurance coverage? Empirical evidence on policyholder dynamics*. 269-300. Long-term health insurance contracts provide policyholders with the option of lapsing coverage or switching to another tariff within the same insurance company. We empirically analyze policyholder behavior regarding contract commitment in a large data set of German private health insurance contracts. We show that short-term as well as long-term premium development, along with premium adjustment frequency, affect lapse and tariff switch rates. Moreover, the sales channel has a strong impact on switching behavior, indicating that policyholder choice is not fully independent of sales representatives. Our results are important for risk assessment and risk management of portfolios of health insurance contracts and provide better understanding of the dynamics of policyholder behavior in health insurance.

HANEWALD, KATJA; POST, THOMAS; SHERRIS, MICHAEL. *Portfolio choice in retirement — what is the optimal home equity release product?* 421-446. We study the decision problem of the optimal choice between home equity release products from a retired homeowner's perspective in the presence of longevity, long-term care, house price, and interest rate risk. The individual can choose to release home equity using reverse mortgages or home reversion plans, to buy annuities, and long-term care insurance. The individual enjoys utility gains from having access to either one of the two equity release products. Higher utility gains are found for the reverse mortgage, as its product features allow for higher lump-sum payouts and provide downside protection for house prices.

LEHR, BRANDON. *Optimal social insurance for heterogeneous agents with private insurance*. 301-333. This article analytically characterizes optimal social insurance in an economy with both ex ante heterogeneity and ex post risk, decomposing the benefits of social insurance into a redistributive and insurance benefit. Agents exert effort to increase the likelihood of high outcome events and are additionally supplied actuarially fair private insurance for this earnings risk. This article is novel in its joint consideration of two sources of heterogeneity, two potential sources of insurance, and an endogenous ex post distribution of outcomes. The introduction of optimal private insurance eliminates the insurance benefit of social insurance, but leaves the redistributive benefit intact. An income effect induced by the crowding out of private insurance generates an additional benefit to social insurance when it takes the form of a linear income tax. Finally, numerical simulations illustrate how the relative contributions of ex ante and ex post risk differentially impact the welfare loss associated with setting optimal social insurance without recognizing the presence of private insurance.

MILLO, GIOVANNI. *The income elasticity of nonlife insurance: a reassessment*. 335-362. In aggregate insurance regressions at the country level, the question whether insurance is a normal or superior good translates into whether income elasticity is significantly greater than one or not. Twenty-five years after a seminal article, I reassess the income elasticity of nonlife insurance by means of homogeneous and heterogeneous versions of the common correlated effects estimator, controlling for common factors and individual trends and characterizing the average behavior of insurance markets while allowing for individual heterogeneity. The evidence supports the existence of a cointegrating behavior between insurance consumption and GDP and the view of nonlife insurance as a normal good.

PETER, RICHARD; RICHTER, ANDREAS; STEINORTH, PETRA. *Yes, no, perhaps? Premium risk and guaranteed renewable insurance contracts with heterogeneous incomplete private information*. 363-385. The article shows that heterogeneous incomplete private information can explain the limited existence of guaranteed renewable health insurance (GR) contracts in an otherwise frictionless markets. We derive a unique equilibrium that can be of the form that either only a portion of the population or none will cover themselves against premium risk with a GR contract. Increased risk aversion, increased premium risk, and first-order stochastic improvements of the distribution of private information increase the likelihood of positive take-up. In case GR contracts are in demand, increased risk aversion and first-order stochastic improvements of the distribution of private information lead to more individuals purchasing the GR contract.

PU, MING; FAN, GANG-ZHI; BAN, CHUNSHENG. *The pricing of mortgage insurance premiums under systematic and idiosyncratic shocks*. 447-474. The recent financial crisis has posed new challenges to the pricing issue of mortgage insurance premiums. By extending an option-based approach to this pricing issue, we attempt to tackle several key challenges including the clustering of mortgage defaults, the diversification effect of underlying property pools, and mortgage insurers' information advantages. Our model partitions the volatility of collateralized property prices into idiosyncratic volatility and systematic volatility. Our results demonstrate that although the rising number of pooled mortgage loans can reduce the volatility of average default losses, the increasing correlation between the collateralized properties can lead to the volatility clustering of these losses.

WADE, CHIP; LIEBENBERG, ANDRE; BLAU, BENJAMIN M. *Information and insurer financial strength ratings: do short sellers anticipate ratings changes?* 475-500. Ratings of financial

institutions have been shown to provide informational value as stock prices generally decrease in response to ratings downgrades. Moreover, insurer's stock prices have been observed to decrease 2 days prior to downgrades, suggesting that informed trading occurs during the predowngrade period. This study examines the trading activity of short sellers surrounding insurer financial strength ratings. We show that short selling is abnormally high during the predowngrade period—indicating that short sellers can predict rating downgrades. Interestingly, we find that predowngrade short selling is driven by stocks of insurers with the most transparent balance sheets. This result suggests that while short sellers can predict rating downgrades generally, the opaqueness of an insurer's assets and liabilities can inhibit informed trading during the predowngrade period.

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BRAZAUSKAS, VYTARAS; KLEEFELD, ANDREAS. *Modeling severity and measuring tail risk of Norwegian fire claims*. 1-16. The probabilistic behavior of the claim severity variable plays a fundamental role in calculation of deductibles, layers, loss elimination ratios, effects of inflation, and other quantities arising in insurance. Among several alternatives for modeling severity, the parametric approach continues to maintain the leading position, which is primarily due to its parsimony and flexibility. In this article, several parametric families are employed to model severity of Norwegian fire claims for the years 1981 through 1992. The probability distributions we consider include generalized Pareto, lognormal-Pareto (two versions), Weibull-Pareto (two versions), and folded-t. Except for the generalized Pareto distribution, the other five models are fairly new proposals that recently appeared in the actuarial literature. We use the maximum likelihood procedure to fit the models and assess the quality of their fits using basic graphical tools (quantile-quantile plots), two goodness-of-fit statistics (Kolmogorov-Smirnov and Anderson-Darling), and two information criteria (AIC and BIC). In addition, we estimate the tail risk of “ground up” Norwegian fire claims using the value-at-risk and tail-conditional median measures. We monitor the tail risk levels over time, for the period 1981 to 1992, and analyze predictive performances of the six probability models. In particular, we compute the next-year probability for a few upper tail events using the fitted models and compare them with the actual probabilities.

CAI, XIAOQIANG; WEN, LIMIN; WU, XIANYI; ZHOU, XIAN. *Response to Liang Hong and Ryan Martin on their comments on our paper entitled ‘Credibility estimation of distribution functions with applications to experience rating in general insurance’, Volume 19(4) 99-100.*

DUNCAN, IAN; LOGINOV, M; LUDKOVSKI, M. *Testing alternative regression frameworks for predictive modeling of health care costs*. 65-87. Predictive models of health care costs have become mainstream in much health care actuarial work. The Affordable Care Act requires the use of predictive modeling-based risk-adjuster models to transfer revenue between different health

exchange participants. Although the predictive accuracy of these models has been investigated in a number of studies, the accuracy and use of models for applications other than risk adjustment have not been the subject of much investigation. We investigate predictive modeling of future health care costs using several statistical techniques. Our analysis was performed based on a dataset of 30,000 insureds containing claims information from two contiguous years. The dataset contains more than 100 covariates for each insured, including detailed breakdown of past costs and causes encoded via coexisting condition flags. We discuss statistical models for the relationship between next-year costs and medical and cost information to predict the mean and quantiles of future cost, ranking risks and identifying most predictive covariates. A comparison of multiple models is presented, including (in addition to the traditional linear regression model underlying risk adjusters) Lasso GLM, multivariate adaptive regression splines, random forests, decision trees, and boosted trees. A detailed performance analysis shows that the traditional regression approach does not perform well and that more accurate models are possible.

MOORE, KRISTEN S; YOUNG, VIRGINIA R. *Minimizing the probability of lifetime ruin when shocks might occur: perturbation analysis*. 17-36. We determine the optimal investment strategy to minimize the probability of an individual's lifetime ruin when the underlying model parameters are subject to a shock. Specifically, we consider two possibilities: (1) changes in the individual's net consumption and mortality rate and (2) changes in the parameters of the financial market. We assume that these rates might change once at a random time. Changes in an individual's net consumption and mortality rate occur when the individual experiences an accident or other unexpected life event, while changes in the financial market occur due to shifts in the economy or in the political climate. We apply perturbation analysis to approximate the probability of lifetime ruin and the corresponding optimal investment strategy for small changes in the model parameters and observe numerically that these approximations are reasonable ones, even when the changes are not small.

NEVES, CÉSAR; FERNANDES, CRISTIANO; VEIGA, ÁLVARO. *Forecasting longevity gains for a population with short time series using a structural SUTSE model: an application to Brazilian annuity plans*. 37-56. In this article, a multivariate structural time series model with common stochastic trends is proposed to forecast longevity gains of a population with a short time series of observed mortality rates, using the information of a related population for which longer mortality time series exist. The state space model proposed here makes use of the seemingly unrelated time series equation and applies the concepts of related series and common trends to construct a proper model to predict the future mortality rates of a population with little available information. This common trends approach works by assuming the two populations' mortality rates are affected by common factors. Further, we show how this model can be used by insurers and pension funds to forecast mortality rates of policyholders and beneficiaries. We apply the proposed model to Brazilian annuity plans where life expectancies and their temporal evolution are predicted using the forecast longevity gains. Finally, to demonstrate how the model can be used in actuarial practice, the best estimate of the liabilities and the capital based on underwriting risk are estimated by means of Monte Carlo simulation. The idiosyncratic risk effect in the process of calculating an amount of underwriting capital is also illustrated using that simulation.

SEBASTIANI, PAOLA; ANDERSEN, STACY L; MCINTOSH, AVERY I; NUSSBAUM, LISA; STEVENSON, MEREDITH D; PIERCE, LESLIE; XIA, SAMANTHA; SALANCE, KELLY; PERLS, THOMAS T. *Familial risk for exceptional longevity*. 57-64. One of the most glaring deficiencies in the current assessment of mortality risk is the lack of information concerning the

impact of familial longevity. In this article we update estimates of sibling relative risk of living to extreme ages using data from more than 1700 sibships, and we begin to examine the trend for heritability for different birth-year cohorts. We also build a network model that can be used to compute the increased chance for exceptional longevity of a subject, conditional on his or her family history of longevity. The network includes familial longevity from three generations and can be used to understand the effects of paternal and maternal longevity on an individual's chance to live to an extreme age.

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ABDALLAH, ANAS; BOUCHER, JEAN-PHILIPPE; COSSETTE, HÉLÈNE; TRUFIN, JULIEN. *Sarmanov family of bivariate distributions for multivariate loss reserving analysis*. 184-200. The correlation among multiple lines of business plays a critical role in aggregating claims and thus determining loss reserves for an insurance portfolio. We show that the Sarmanov family of bivariate distributions is a convenient choice to capture the dependencies introduced by various sources, including the common calendar year, accident year, and development period effects. The density of the bivariate Sarmanov distributions with different marginals can be expressed as a linear combination of products of independent marginal densities. This pseudo-conjugate property greatly reduces the complexity of posterior computations. In a case study, we analyze an insurance portfolio of personal and commercial auto lines from a major US property-casualty insurer.

GETZEN, THOMAS E. *Accuracy of long-range actuarial projections of health care costs*. 101-113. The Office of the Actuary, mandated to provide projections of future medical spending for use by the US Medicare and Medicaid programs, publishes forecasts that have been widely used by private firms and government budget officials as a baseline for expected long-run premium trends and to estimate liabilities for retiree health benefits. Although these projections have been made publicly available since 1986, they have not yet been subject to systematic evaluation by an external reviewer. This article develops a method for assessment of both short- and long-run accuracy and applies it to the 17 sets of projections made public over the last 25 years. The more recent set of projections (1998-2010) incorporating lagged macroeconomic effects appear to be more accurate than the older (1986-1995) projections that relied more heavily on demographic cost of illness trends. The average annualized error of the forecasts is approximately 0.5-1% per year, whether assessed over a span of one, two, or 10 years. Projecting "excess" growth in health spending (the rise in the share of wages or GDP) tends to be more accurate than forecasting nominal or real spending per capita.

LALLY, NATHAN R; HARTMAN, BRIAN M. *Predictive modeling in long-term care insurance*. 160-183. The accurate prediction of long-term care insurance (LTCI) mortality, lapse, and claim rates is essential when making informed pricing and risk management decisions. Unfortunately, academic literature on the subject is sparse and industry practice is limited by software and time constraints. In this article, we review current LTCI industry modeling methodology, which is typically Poisson regression with covariate banding/modification and stepwise variable selection. We test the claim that covariate banding improves predictive accuracy, examine the potential downfalls of stepwise selection, and contend that the assumptions required for Poisson regression

are not appropriate for LTCI data. We propose several alternative models specifically tailored toward count responses with an excess of zeros and overdispersion. Using data from a large LTCI provider, we evaluate the predictive capacity of random forests and generalized linear and additive models with zero-inflated Poisson, negative binomial, and Tweedie errors. These alternatives are compared to previously developed Poisson regression models. Our study confirms that variable modification is unnecessary at best and automatic stepwise model selection is dangerous. After demonstrating severe overprediction of LTCI mortality and lapse rates under the Poisson assumption, we show that a Tweedie GLM enables much more accurate predictions. Our Tweedie regression models improve average predictive accuracy (measured by several prediction error statistics) over Poisson regression models by as much as four times for mortality rates and 17 times for lapse rates.

MAEGEBIER, ALEXANDER; GATZERT, NADINE. *The impact of disability insurance on a portfolio of life insurances*. 142-159. The aim of this article is to study the impact of disability insurance on an insurer's risk situation for a portfolio that also consists of annuity and term life contracts. We provide a model framework using discrete time nonhomogeneous bivariate Markov renewal processes and in a simulation study focus on diversification benefits as well as potential natural hedging effects (risk-minimizing or risk-immunizing portfolio compositions) that may arise within the portfolio because of the different types of biometric risks. Our analyses emphasize that disability insurances are a less efficient tool to hedge shocks to mortality and that their high sensitivity toward shocks to disability risks cannot be easily counterbalanced by other life insurance products. However, the addition of disability insurance can still considerably lower the overall company risk.

SHI, PENG; HARTMAN, BRIAN M. *Credibility in loss reserving*. 114-132. This article proposes using credibility theory in the context of stochastic claims reserving. We consider the situation where an insurer has access to the claims experience of its peer competitors and has the potential to improve prediction of outstanding liabilities by incorporating information from other insurers. Based on the framework of Bayesian linear models, we show that the development factor in the classical chain-ladder setting has a credibility expression: a weighted average of the prior mean and the best estimate from the data. In the empirical analysis, we examine loss triangles for the line of commercial auto insurance from a portfolio of insurers in the United States. We employ hierarchical model for the specification of prior and show that prediction could be improved through borrowing strength among insurers based on a hold-out sample validation.

SU, FEI; CHAN, KUNG-SIK. *Option pricing with threshold diffusion processes*. 133-141. The threshold diffusion (TD) model assumes a piecewise linear drift term and piecewise smooth diffusion term, which can capture many nonlinear features and volatility clustering often observed in financial time series data. We solve the problem of option pricing with a TD asset pricing process by deriving the minimum entropy martingale measure, which is the risk-neutral measure closest to the underlying TD probability measure in terms of Kullback-Leibler divergence, given the historical regime-switching pattern. The proposed valuation model is illustrated with a numerical example.

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CHEUNG, ERIC C K; WOO, JAE-KYUNG. *On the discounted aggregate claim costs until ruin in dependent Sparre Andersen risk processes.* 63-91. In this paper, a dependent Sparre Andersen risk process in which the joint density of the interclaim time and the resulting claim severity satisfies the factorization as in Willmot and Woo [Willmot, G.E., Woo, J.-K. (2012), On the analysis of a general class of dependent risk processes. *Insurance: Mathematics and Economics* 51(1): 134-141] is considered. We study a generalization of the Gerber-Shiu function (i) whose penalty function further depends on the surplus level immediately after the second last claim before ruin; and (ii) which involves the moments of the discounted aggregate claim costs until ruin. The generalized discounted density with a moment-based component proposed in Cheung [Cheung, E. C.K. (2011). A generalized penalty function in Sparre-Andersen risk models with surplus-dependent premium, *Insurance: Mathematics and Economics* 48(3): 384-397] plays a key role in deriving recursive defective renewal equations. We pay special attention to the case where the marginal distribution of the interclaim times is Coxian, and the required components in the recursion are obtained. A reverse type of dependency structure, where the claim severities follow a combination of exponentials, is also briefly discussed, and this leads to a nice explicit expression for the expected discounted aggregate claims until ruin. Our results are applied to generate some numerical examples involving (i) the covariance of the time of ruin and the discounted aggregate claims until ruin; and (ii) the expectation, variance and third central moment of the discounted aggregate claims until ruin.

LIANG, ZHIBIN; YUEN, KAM CHUEN. *Optimal dynamic reinsurance with dependent risks: variance premium principle.* 18-36. In this paper, we consider the optimal proportional reinsurance strategy in a risk model with two dependent classes of insurance business, where the two claim number processes are correlated through a common shock component. Under the criterion of maximizing the expected exponential utility with the variance premium principle, we adopt a nonstandard approach to examining the existence and uniqueness of the optimal reinsurance strategy. Using the technique of stochastic control theory, closed-form expressions for the optimal strategy and the value function are derived for the compound Poisson risk model as well as for the Brownian motion risk model. From the numerical examples, we see that the optimal results for the compound Poisson risk model are very different from those for the diffusion model. The former depends not only on the safety loading, time, and the interest rate, but also on the claim size distributions and the claim number processes, while the latter depends only on the safety loading, time, and the interest rate.

SHEN, YANG; WEI, JIAQIN. *Optimal investment-consumption-insurance with random parameters.* 37-62. This paper discusses an optimal investment, consumption, and life insurance purchase problem for a wage earner in a complete market with Brownian information. Specifically, we assume that the parameters governing the market model and the wage earner, including the interest rate, appreciation rate, volatility, force of mortality, premium-insurance ratio, income and discount rate, are all random processes adapted to the Brownian motion filtration. Our modeling framework is very general, which allows these random parameters to be unbounded, non-Markovian functionals of the underlying Brownian motion. Suppose that the wage earner's preference is described by a power utility. The wage earner's problem is then to choose an optimal investment-consumption-insurance strategy so as to maximize the expected,

discounted utilities from intertemporal consumption, legacy and terminal wealth over an uncertain lifetime horizon. We use a novel approach, which combines the Hamilton-Jacobi-Bellman equation and backward stochastic differential equation (BSDE) to solve this problem. In general, we give explicit expressions for the optimal investment-consumption-insurance strategy and the value function in terms of the solutions to two BSDEs. To illustrate our results, we provide closed-form solutions to the problem with stochastic income, stochastic mortality, and stochastic appreciation rate, respectively.

YANG, HAIZHONG; GAO, WEI; LI, JINZHU. *Asymptotic ruin probabilities for a discrete-time risk model with dependent insurance and financial risks*. 1-17. This contribution focuses on a discrete-time risk model in which both insurance risk and financial risk are taken into account and they are equipped with a wide type of dependence structure. We derive precise asymptotic formulas for the ruin probabilities when the insurance risk has a dominatedly varying tail. In the special case of regular variation, the corresponding formula is proved to be uniform for the time horizon.

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BARRIEU, PAULINE; VERAART, LUITGARD A M. *Pricing q -forward contracts: an evaluation of estimation window and pricing method under different mortality models*. 146-166. The aim of this paper is to study the impact of various sources of uncertainty on the pricing of a special longevity-based instrument: a q -forward contract. At the expiry of a q -forward contract, the realized mortality rate for a given population is exchanged in return for a fixed (mortality) rate that is agreed at the initiation of the contract. Pricing a q -forward involves determining this fixed rate. In our study, we disentangle three main sources of uncertainty and consider their impact on pricing: model choice for the underlying mortality rate, time-window used for estimation and the pricing method itself.

LEPPISAARI, MATIAS. *Modeling catastrophic deaths using EVT with a microsimulation approach to reinsurance pricing*. 113-145. Recently, a marked Poisson process (MPP) model for life catastrophe risk was proposed in Ekhedden & Hössjer (2014) [Ekhedden, E., Hössjer, O. (2014), Pricing catastrophe risk in life (re)insurance. Scandinavian Actuarial Journal 4: 352-367]. We provide a justification and further support for the model by considering more general Poisson point processes in the context of extreme value theory (EVT), and basing the choice of model on statistical tests and model comparisons. A case study examining accidental deaths in the Finnish population is provided. We further extend the applicability of the catastrophe risk model by considering small and big accidents separately; the resulting combined MPP model can flexibly capture the whole range of accidental death counts. Using the proposed model, we present a simulation framework for pricing (life) catastrophe reinsurance, based on modeling the underlying policies at individual contract level. The accidents are first simulated at population level, and their effect on a specific insurance company is then determined by explicitly simulating the resulting insured deaths. The proposed microsimulation approach can potentially lead to more accurate results than the traditional methods, and to a better view of risk, as it can make use of all the information available to the re/insurer and can explicitly accommodate even complex re/insurance terms and product features. As an example, we price several excess reinsurance contracts. The proposed simulation model is also suitable for solvency assessment.

OHLSSON, ESBJÖRN. *Unallocated loss adjustment expense reserving*. 167-180. In non-life insurance, the provision for outstanding claims (the claims reserve) should include future loss adjustment expenses, i.e. administrative expenses to settle the claims, and therefore we have to estimate the expected Unallocated Loss Adjustment Expenses (ULAE) – expenses that are not attributable to individual claims, such as salaries at the claims handling department. The ULAE reserve has received little attention from European actuaries in the literature, supposedly because of the lack of detailed data for estimation and evaluation. Having good estimation procedures will, however, become even more important with the introduction of the Solvency II regulations, which require unbiased estimation of future cash flows for all expenses. We present a model for ULAE at the individual claim level that includes both fixed and variable costs. This model leads to an estimate of the ULAE reserve at the aggregate (line-of-business) level, as demonstrated in a numerical example from a Swedish non-life insurer.

YANG, BOWEN; LI, JACKIE; BALASOORIYA, UDITHA. *Cohort extensions of the Poisson common factor model for modelling both genders jointly*. 93-112. The earlier work on mortality modelling and forecasting has largely focused on the study of a single population. Recently, there is an emerging strand of literature that emphasises the interrelationship between multiple populations. In this paper, we examine some cohort extensions of the Poisson common factor model for modelling both genders jointly. The cohort effect is specified in six alternatives which are applied to data-sets from five developed regions. We find that direct parameterisation of cohort effect could improve model fitting, reduce the need for additional period factors, and produce consistent mortality forecasts for females and males. Furthermore, we find that the cohort effect appears to be gender indifferent for the populations examined and has an interaction effect with age in certain cases.

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BENKHELIFA, LAZHAR. *Kernel-type estimators for the distortion risk premiums of heavy-tailed distributions*. 262-278. A new kernel-type estimator for the distortion risk premiums of heavy-tailed losses is introduced. Using a least-squares approach, a bias-reduced version of this estimator is proposed. Under suitable assumptions, the asymptotic normality of the given estimators is established. A small simulation study, to illustrate the performance of our method, is carried out.

DE ANGELIS, PAOLO; MARTIRE, ANTONIO LUCIANO; RUSSO, EMILIO. *A bivariate model for evaluating equity-linked policies with surrender option*. 246-261. This article proposes a bivariate lattice model for evaluating equity-linked policies embedding a surrender option when the underlying equity dynamics is described by a geometric Brownian motion with stochastic interest rate. The main advantage of the model stays in that the original processes for the reference fund and the interest rate are directly discretized by means of lattice approximations, without resorting to any additional transformation. Then, the arising lattices are combined in order to establish a bivariate tree where equity-linked policy premiums are computed by discounting the policy payoff over the lattice branches, and allowing early exercise at each premium payment date to model the surrender decision.

GOLUBIN, A Y. *Optimal insurance and reinsurance policies chosen jointly in the individual risk model*. 181-197. The paper studies the so-called individual risk model where both a policy of

per-claim insurance and a policy of reinsurance are chosen jointly by the insurer in order to maximize his/her expected utility. The insurance and reinsurance premiums are defined by the expected value principle. The problem is solved under additional constraints on the reinsurer's risk and the residual risk of the insured. It is shown that the solution to the problem is the following: The optimal reinsurance is a modification of stop-loss reinsurance policy, so-called stop-loss reinsurance with an upper limit; the optimal insurer's indemnity is a combination of stop-loss- and deductible policies. The results are illustrated by a numerical example for the case of exponential utility function. The effects of changing model parameters on optimal insurance and reinsurance policies are considered.

JIN, TAO; PROVOST, SERGE B; REN, JIANDONG. *Moment-based density approximations for aggregate losses*. 216-245. The determination of the distribution of aggregate losses is of crucial importance for an insurer. In this paper, we propose a technique for approximating the distribution of univariate and bivariate aggregate losses, which is solely based on their moments. Accordingly, this methodology can be implemented without any specific knowledge of the claim number or size distributions. The numerical examples presented herein indicate that the proposed approach constitutes a viable alternative to the commonly used recursive and FFT [fast Fourier transform] methods.

SHI, PENG. *Insurance ratemaking using a copula-based multivariate Tweedie model*. 198-215. The Tweedie distribution, featured with a mass probability at zero, is a convenient tool for insurance claims modeling and pure premium determination in general insurance. Motivated by the fact that an insurance policy typically provides multiple types of coverage, we propose a copula-based multivariate Tweedie regression for modeling the semi-continuous claims while accommodating the association among different types. The proposed approach also allows for dispersion modeling, resulting in a multivariate version of the double generalized linear model. We demonstrate the application in insurance ratemaking using a portfolio of policyholders of automobile insurance from the state of Massachusetts in the United States.

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CURRIE, IAIN D. *On fitting generalized linear and non-linear models of mortality*. 356-383. Many common models of mortality can be expressed compactly in the language of either generalized linear models or generalized non-linear models. The R language provides a description of these models which parallels the usual algebraic definitions but has the advantage of a transparent and flexible model specification. We compare eight model structures for mortality. For each structure, we consider (a) the Poisson models for the force of mortality with both log and logit link functions and (b) the binomial models for the rate of mortality with logit and complementary log-log link functions. Part of this work shows how to extend the usual smooth two-dimensional P-spline model for the force of mortality with Poisson error and log link to the other smooth two-dimensional P-spline models with Poisson and binomial errors defined in (a) and (b). Our comments are based on the results of fitting these models to data from six countries: Australia, France, Japan, Sweden, UK and USA. We also discuss the possibility of forecasting with these models; in particular, the introduction of cohort terms generally leads to an improvement in overall fit, but can also make forecasting with these models problematic.

CZARNA, IRMINA. *Parisian ruin probability with a lower ultimate bankrupt barrier*. 319-337. The paper deals with a ruin problem, where there is a Parisian delay and a lower ultimate bankrupt barrier. In this problem, we will say that a risk process gets ruined when it stays below zero longer than a fixed amount of time $\zeta > 0$ or goes below a fixed level $-a$. We focus on a general spectrally negative Lévy insurance risk process. For this class of processes, we identify the Laplace transform of the ruin probability in terms of so-called q -scale functions. We find its Cramér-type and convolution-equivalent asymptotics when reserves tend to infinity. Finally, we analyze few explicit examples.

PLANCHET, FRÉDÉRIC; TOMAS, JULIEN. *Uncertainty on survival probabilities and solvency capital requirement: application to long-term care insurance*. 279-292. In this paper, we focus on uncertainty issues on disabled lives survival probabilities of LTC insurance policyholders and its consequences on solvency capital requirement. Among the risks affecting long-term care portfolios, special attention is addressed to the table risk, i.e. the risk of unanticipated aggregate mortality, arising from the uncertainty in modeling LTC claimants survival law. The table risk can be thought as the risk of systematic deviations referring not only to a parameter risk but, as well, to any other sources leading to a misinterpretation of the life table resulting for example from an evolution of medical techniques or a change in rules of acceptance. In fine, the idea is to introduce the risk of systematic deviations arising from the uncertainty on the disabled lives death probabilities directly. We analyze the consequences of an error of appreciation on the disabled lives survival probabilities in terms of level of reserves and describe a framework in an Own Risk and Solvency Assessment perspective to measure the gap between the risk profile from the standard formula to the risk analysis specific to the organism.

WANG, CHOU-WEN; HUANG, HONG-CHIH; LEE, YUNG-TSUNG. *On the valuation of reverse mortgage insurance*. 293-318. This article presents a closed-form formula for calculating the loan-to-value (LTV) ratio in an adjusted-rate reverse mortgage (RM) with a lump sum payment. Previous literatures consider the pricing of RM in a constant interest rate assumption and price it on fixed-rate loans. This paper successfully considers the dynamic of interest rate and the adjustable-rate RM simultaneously. This paper also considers the housing price shock into the valuation model. Assuming that house prices follow a jump diffusion process with a stochastic interest rate and that the loan interest rate is adjusted instantaneously according to the short rate, we demonstrate that the LTV ratio is independent of the term structure of interest rates. This argument holds even when housing prices follow a general process: an exponential Lévy process. In addition, the HECM (Home Equity Conversion Mortgage) program may be not sustainable, especially for a higher level of housing price volatility. Finally, when the loan interest rate is adjusted periodically according to the LIBOR rate, our finding reveals that the LTV ratio is insensitive to the parameters characterizing the CIR model.

ZADEH, AMIN HASSAN; STANFORD, DAVID A. *Bayesian and Bühlmann credibility for phase-type distributions with a univariate risk parameter*. 338-355. Credibility theory is a statistical tool to calculate the premium for the next period based on past claims experience and the manual rate. Each contract is characterized by a risk parameter. A phase-type (or PH) random variable, which is defined as the time until absorption in a continuous-time Markov chain, is fully characterized by two sets of parameters from that Markov chain: the initial probability vector and transition intensity matrix. In this article, we identify an interpretable univariate risk parameter from amongst the many candidate parameters, by means of uniformization. The resulting density form is then expressed as an infinite mixture of Erlang distributions. These results are used to obtain a

tractable likelihood function by a recursive formula. Then the best estimator for the next premium, i.e. the Bayesian premium, as well as its approximation by the Bühlmann credibility premium are calculated. Finally, actuarial calculations for the Bühlmann and Bayesian premiums are investigated in the context of a gamma prior, and illustrated by simulated data in a series of examples.

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BACINELLO, ANNA RITA; MILLOSSOVICH, PIETRO; MONTEALEGRE, ALVARO. *The valuation of GMWB variable annuities under alternative fund distributions and policyholder behaviours*. 446-465. In this paper, we present a dynamic programming algorithm for pricing variable annuities with Guaranteed Minimum Withdrawal Benefits (GMWB) under a general Lévy processes framework. The GMWB gives the policyholder the right to make periodical withdrawals from her policy account even when the value of this account is exhausted. Typically, the total amount guaranteed for withdrawals coincides with her initial investment, providing then a protection against downside market risk. At each withdrawal date, the policyholder has to decide whether, and how much, to withdraw, or to surrender the contract. We show how different policyholder's withdrawal behaviours can be modelled. We perform a sensitivity analysis comparing the numerical results obtained for different contractual and market parameters, policyholder behaviours and different types of Lévy processes.

BERNARD, CAROLE; KWAK, MINSUK. *Dynamic preferences for popular investment strategies in pension funds*. 398-419. In this paper, we characterize dynamic investment strategies that are consistent with the expected utility setting and more generally with the forward utility setting. Two popular dynamic strategies in the pension funds industry are used to illustrate our results: a constant proportion portfolio insurance (CPPI) strategy and a life-cycle strategy. For the CPPI strategy, we are able to infer preferences of the pension fund's manager from her investment strategy, and to exhibit the specific expected utility maximization that makes this strategy optimal at any given time horizon. In the Black-Scholes market with deterministic parameters, we are able to show that traditional life-cycle funds are not optimal to any expected utility maximizers. We also prove that a CPPI strategy is optimal for a fund manager with HARA utility function, while an investor with a SAHARA utility function will choose a time-decreasing allocation to risky assets in the same spirit as the life-cycle funds strategy. Finally, we suggest how to modify these strategies if the financial market follows a more general diffusion process than in the Black-Scholes market.

CHOI, SUN-YONG; KIM, JEONG-HOON. *Equity-linked annuities with multiscale hybrid stochastic and local volatility*. 466-487. In recent times, hybrid underlying models have become an industry standard for the pricing of derivatives and other problems in finance. This paper chooses a hybrid stochastic and local volatility model to evaluate an equity-linked annuity (ELA), which is a sort of tax-deferred annuity whose credited interest is linked to an equity index. The stochastic volatility component of the hybrid model is driven by a fast mean-reverting diffusion process while the local volatility component is given by the constant elasticity of variance (CEV) model. Since contracts of the ELA usually have long maturities over 10 years, a slowly moving factor in the stochastic volatility of stock index is expected to play a significant role in the valuation of the

ELA, and thus, it is added to the aforementioned model. Based on this multiscale hybrid model, an analytic approximate formula is obtained for the price of a European option in terms of the CEV probability density function and then the result is applied to the value of the point-to-point ELA. The formula leads to the dependence structure of the ELA price on the fast and slow scale stochastic volatility and the elasticity of variance.

JIANG, WUYUAN; YANG, ZHAOJUN. *The maximum surplus before ruin for dependent risk models through Farlie-Gumbel-Morgenstern copula*. 385-397. We extend the classical compound Poisson risk model to consider the distribution of the maximum surplus before ruin where the claim sizes depend on inter-claim times via the Farlie-Gumbel-Morgenstern copula. We derive an integro-differential equation with certain boundary conditions for this distribution, of which the Laplace transform is provided. We obtain the renewal equation and explicit expressions for this distribution are derived when the claim amounts are exponentially distributed. Finally, we present numerical examples.

LI, SHUANMING; LU, YI. *On the time and the number of claims when the surplus drops below a certain level*. 420-445. In this paper, we define $T_z(u)$ to be the first time that the surplus process drops below a certain level z from the initial surplus u ($> z$) for a risk model with interest. A generalized Gerber-Shiu-type function is then defined based on the first time and the number of claims that the surplus drops below z from u , and other $T_z(u)$ -related random variables. Explicit expressions for this function, when $u = z$, and when $u > z$ under exponential claims, are obtained. We then obtain the moments and probability function (with numerical examples) of the number of claims until $T_z(u)$. We also investigate a joint transform function of the two-sided first exit time and the number of claims until then, and obtain the probability of the surplus hitting an upper level from the initial surplus without having dropped below a lower level with Erlang(2) claims.

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CHRISTIANSEN, MARCUS CHRISTIAN; HENRIKSEN, LARS FREDERIK BRANDT; SCHOMACKER, KRISTIAN JUUL; STEFFENSEN, MOGENS. *Stress scenario generation for solvency and risk management*. 502-529. We derive worst-case scenarios in a life insurance model in the case where the interest rate and the various transition intensities are mutually dependent. Examples of this dependence are that (a) surrender intensities and interest rates are high at the same time, (b) mortality intensities of a policyholder as active and disabled, respectively, are low at the same time, and (c) mortality intensities of the policyholders in a portfolio are low at the same time. The set from which the worst-case scenario is taken reflects the dependence structure and allows us to relate the worst-case scenario-based reserve, qualitatively, to a Value-at-Risk-based calculation of solvency capital requirements. This brings out perspectives for our results in relation to qualifying the standard formula of Solvency II or using a scenario-based approach in internal models. Our results are powerful for various applications and the techniques are non-standard in control theory, exactly because our worst-case scenario is deterministic and not adapted to the stochastic development of the portfolio. The formalistic results are exemplified in a series of numerical studies.

HAUGEN, MARION; MOGER, TRON ANDERS. *Frailty modelling of time-to-lapse of single policies for customers holding multiple car contracts*. 489-501. Corporate customers often hold

multiple contracts and this might give dependence between the lapsing times of the single policies. We present a shared gamma frailty model in order to study the time-to-lapse of single car policies for customers holding multiple car contracts with the same insurance company, accounting for measured and time-dependent covariates. Customers with the highest frailty value tend to leave the company earlier than the others and finding these is a central aspect within a company's customer relationship management strategy. We estimate conditional survival curves which illustrate the decreased survival probability of a customer after a lapse in a single car insurance policy. The individual survival curves are overestimated if the underlying association for cars with the same customer is ignored. Fitting misspecified Cox's proportional hazards model also results in an underestimation of the standard error of the parameter estimates.

LEE, WING YAN; WILLMOT, GORDON E. *The moments of the time to ruin in dependent Sparre Andersen models with Coxian claim sizes.* 550-564. A very general class of dependent Sparre Andersen models with Coxian claim sizes (e.g. Landriault et al. 2014) [Landriault, D., Lee, W. Y., Willmot, G. E. & Woo, J.-K., (2014), A note on deficit analysis in dependency models involving Coxian claim amounts. *Scandinavian Actuarial Journal*. 5: 405-423] is considered in this paper. The moments of the time to ruin are studied under this class. An analytical form is provided for the moments, which involves solving linear systems of equations. Numerical examples are then considered to further study the properties of the mean and variance of the time to ruin.

LUONG, ANDREW. *Cramér-Von Mises distance estimation for some positive infinitely divisible parametric families with actuarial applications.* 530-549. Cramér-Von Mises (CVM) inference techniques are developed for some positive flexible infinitely divisible parametric families generalizing the compound Poisson family. These larger families appear to be useful for parametric inference for positive data. The methods are based on inverting the characteristic functions. They are numerically implementable whenever the characteristic function has a closed form. In general, likelihood methods based on density functions are more difficult to implement. CVM methods also lead to model testing, with test statistics asymptotically following a chi-square distribution. The methods are for continuous models, but they can also handle models with a discontinuity point at the origin such as the case of compound Poisson models. Simulation studies seem to suggest that CVM estimators are more efficient than moment estimators for the common range of the compound Poisson gamma family. Actuarial applications include estimation of the stop loss premium, and estimation of the present value of cash flows when interest rates are assumed to be driven by a corresponding Lévy process.

YANG, YANG; YUEN, KAM CHUEN. *Asymptotics for a discrete-time risk model with Gamma-like insurance risks.* 565-579. Consider a discrete-time insurance risk model with insurance and financial risks. Within period i , the net insurance loss is denoted by X_i and the stochastic discount factor over the same time period is denoted by Y_i . Assume that $\{X_i, i \geq 1\}$ for a sequence of independent and identically distributed real-valued random variables with common distribution F ; $\{Y_i, i \geq 1\}$; are another sequence of independent and identically distributed positive random variables with common distribution G ; and the two sequences are mutually independent. Under the assumptions that F is Gamma-like tailed and G has a finite upper endpoint, we derive some precise formulas for the tail probability of the present value of aggregate net losses and the finite-time and infinite-time ruin probabilities. As an extension, a dependent risk model is considered, where each random pair of the net loss and the discount factor follows a bivariate Sarmanov distribution.

CAI, JUN. *Optimal reinsurance with expectile*. 624-645. In this paper, we study optimal reinsurance treaties that minimize the liability of an insurer. The liability is defined as the actuarial reserve on an insurer's risk exposure plus the risk margin required for the risk exposure. The risk margin is determined by the risk measure of expectile. Among a general class of reinsurance premium principles, we prove that a two-layer reinsurance treaty is optimal. Furthermore, if a reinsurance premium principle in the class is translation invariant or is the expected value principle, we show that a one-layer reinsurance treaty is optimal. Moreover, we use the expected value premium principle and Wang's premium principle to demonstrate how the parameters in an optimal reinsurance treaty can be determined explicitly under a given premium principle.

LIN, XIANG; QIAN, YIPING. *Time-consistent mean-variance reinsurance-investment strategy for insurers under CEV mode*. 646-671. We consider an optimal time-consistent reinsurance-investment strategy selection problem for an insurer whose surplus is governed by a compound Poisson risk model. In our model, the insurer transfers part of the risk due to insurance claims via a proportional reinsurance and invests the surplus in a simplified financial market consisting of a risk-free asset and a risky stock. The dynamics of the risky stock is governed by a constant elasticity of variance model to incorporate conditional heteroscedasticity as well as the feedback effect of an asset's price on its volatility. The objective of the insurer is to choose an optimal time-consistent reinsurance-investment strategy so as to maximize the expected terminal surplus while minimizing the variance of the terminal surplus. We investigate the problem using the Hamilton-Jacobi-Bellman dynamic programming approach. Closed-form solutions for the optimal reinsurance-investment strategies and the corresponding value functions are obtained in both the compound Poisson risk model and its diffusion approximation. Numerical examples are also provided to illustrate how the optimal reinsurance-investment strategy changes when some model parameters vary.

RIEGEL, ULRICH. *Bifurcation of attritional and large losses in an additive IBNR environment*. 604-623. In certain segments, IBNR calculations on paid triangles are more stable than on incurred triangles. However, calculations on payments often do not adequately take large losses into account. An IBNR method which separates large and attritional losses and thus allows to use payments for the attritional and incurred amounts for the large losses has been introduced by Riegel (Riegel, U. (2014). A bifurcation approach for attritional and large losses in chain ladder calculations, *Astin Bulletin* 44: 127-172). The method corresponds to a stochastic model that is based on Mack's chain ladder model. In this paper, we analyse a quasi-additive version of this model, i.e. a version which is in essence based on the assumptions of the additive (or incremental loss ratio) method. We describe the corresponding IBNR method and derive formulas for the mean squared error of prediction.

VAN BERKUM, FRANK; ANTONIO, KATRIEN; VELLEKOOP, M H. *The impact of multiple structural changes on mortality predictions*. 581-603. Most mortality models proposed in recent literature rely on the standard ARIMA framework (in particular: a random walk with drift) to project mortality rates. As a result the projections are highly sensitive to the calibration period. We therefore analyse the impact of allowing for multiple structural changes on a large collection of mortality models. We find that this may lead to more robust projections for the period effect

but that there is only a limited effect on the ranking of the models based on backtesting criteria, since there is often not yet sufficient statistical evidence for structural changes. However, there are cases for which we do find improvements in estimates and we therefore conclude that one should not exclude on beforehand that structural changes may have occurred.

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ALAI, DANIEL H; LANDSMAN, ZINOVYI M; SHERRIS, MICHAEL. *Multivariate Tweedie lifetimes: the impact of dependence*. 692-712. Systematic longevity risk is increasingly relevant for public pension schemes and insurance companies that provide life benefits. In view of this, mortality models should incorporate dependence between lives. However, the independent lifetime assumption is still heavily relied upon in the risk management of life insurance and annuity portfolios. This paper applies a multivariate Tweedie distribution to incorporate dependence, which it induces through a common shock component. Model parameter estimation is developed based on the method of moments and generalized to allow for truncated observations. The estimation procedure is explicitly developed for various important distributions belonging to the Tweedie family, and finally assessed using simulation.

JAKOBSONS, EDGARS; HAN, XIAOYING; WANG, RUODU. *General convex order on risk aggregation*. 713-740. Using a general notion of convex order, we derive general lower bounds for risk measures of aggregated positions under dependence uncertainty, and this in arbitrary dimensions and for heterogeneous models. We also prove sharpness of the bounds obtained when each marginal distribution has a decreasing density. The main result answers a long-standing open question and yields an insight in optimal dependence structures. A numerical algorithm provides bounds for quantities of interest in risk management. Furthermore, our numerical results suggest that the bounds obtained in this paper are generally sharp for a broader class of models.

LUO, SHANGZHEN; WANG, MIN; ZENG, XUDONG. *Optimal reinsurance: minimize the expected time to reach a goal*. 741-762. In this paper, we consider an optimal reinsurance problem. The surplus model of the insurance company is approximated by a diffusion model with the drift coefficient μ . The insurance company employs reinsurance to reduce the risk. π is the proportion of each claim paid by the company and the remainder proportion of the claim is paid by the reinsurer. $\lambda(1 - \pi)$ is the rate at which the premiums are diverted to the reinsurer, thus it holds $\lambda \geq \mu > 0$ in general. We discuss two cases: (i) non-cheap reinsurance (when $\lambda > \mu$), (ii) cheap reinsurance (when $\lambda = \mu$). The objective of the insurance company is to make an optimal decision on reinsurance to reach a goal (a given surplus level) in minimal expected time. We disclose that for some case it is not suitable to search optimal decisions by minimizing the expected time to reach a goal. In order to deal with this case, we study two other methodologies (ruin probability minimization and expected discount factor maximization) for the optimal strategy selection problem in reinsurance decision.

MALINOVSKII, VSEVOLOD K. *How an aggressively expanding insurance company becomes insolvent*. 673-691. This paper aims to model a rational firm expanding on a regulated competitive insurance market. While the market is profitable, an aggressive price cut makes the firm's market shares and revenue climb due to immigration of insureds. But the revenue's growth may

be slower than the growth in reserves needed to maintain the annual probabilities of ruin equal to a legally predetermined value. It will result in a progressive run-out of the funds allocated for the company's strategic growth and is fraught with inability to meet the legal solvency requirements.

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