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ASTIN Bulletin

45(1), 2015

AASE, KNUT K. *Life insurance and pension contracts I: The time additive life cycle model*. 1–47.

We analyze optimal consumption in the life cycle model by introducing life and pension insurance contracts. The model contains a credit market with biometric risk, and market risk via risky securities. This idealized framework enables us to clarify important aspects of life insurance and pension contracts. We find optimal pension plans and life insurance contracts where the benefits are state dependent. We compare these solutions both to the ones of standard actuarial theory, and to policies offered in practice. Implications of this include what role the insurance industry may play to improve welfare. The relationship between substitution of consumption and risk aversion is highlighted in the presence of a consumption puzzle. One problem related portfolio choice is discussed the horizon problem. Finally, we present some comments on longevity risk and cohort risk.

DONNELLY, CATHERINE. *Actuarial fairness and solidarity in pooled annuity funds*. 49–74.

Various types of structures that enable a group of individuals to pool their mortality risk have been proposed in the literature. Collectively, the structures are called pooled annuity funds. Since the pooled annuity funds propose different methods of pooling mortality risk, we investigate the connections between them and find that they are genuinely different for a finite heterogeneous membership profile. We discuss the importance of actuarial fairness, defined as the expected benefits equalling the contributions for each member, in the context of pooling mortality risk and comment on whether actuarial unfairness can be seen as solidarity between members. We show that, with a finite number of members in the fund, the group self-annuitization scheme is not actuarially fair: some members subsidize the other members. The implication is that the members who are subsidizing the others may obtain a higher expected benefit by joining a fund with a more favorable membership profile. However, we find that the subsidies are financially significant only for very small or highly heterogeneous membership profiles.

HASHORVA, ENKELEJD; RATOVOMIRIJA, GILDAS. *On Sarmanov mixed Erlang risks in insurance applications*. 175–205. In this paper we consider an extension to the aggregation of the FGM mixed Erlang risks, proposed by Cossette *et al.* (2013 Insurance: Mathematics and Economics, 52, 560–572), in which we introduce the Sarmanov distribution to model the dependence

structure. For our framework, we demonstrate that the aggregated risk belongs to the class of Erlang mixtures. Following results from S. C. K. Lee and X. S. Lin (2010) [*North American Actuarial Journal*, 14(1) 107–130], G. E. Willmot and X. S. Lin (2011) [*Applied Stochastic Models in Business and Industry*, 27(1) 8–22], analytical expressions of the contribution of each individual risk to the economic capital for the entire portfolio are derived under both the TVaR and the covariance capital allocation principle. By analysing the commonly used dependence measures, we also show that the dependence structure is wide and flexible. Numerical examples and simulation studies illustrate the tractability of our approach.

MUSAKWA, FIDELIS T. *Pricing a motor extended warranty with limited usage cover*. 101–125.

Providers of motor extended warranties with limited usage often face difficulty evaluating the impact of usage limits on warranty price because of incomplete usage data. To address this problem, this paper employs a non-parametric interval-censored survival model of time to accumulate a specific usage. This is used to develop an estimator of the probability that a provider is on risk at a specific time in service. The resulting pricing model is applied to a truck extended warranty case study. The case study demonstrates that interval-censored survival models are ideal for use in pricing motor extended warranties with limited usage cover. The results also suggest that employing a usage rate distribution to forecast the number of vehicles on risk can be misleading, especially on an extended warranty with a relatively high usage limit.

RODRÍGUEZ-MARTÍNEZ, EUGENIO V; CARDOSO, RUI M R; EGÍDIO DOS REIS, ALFREDO D.

Some advances on the Erlang(n) dual risk model. 127–150. The dual risk model assumes that the surplus of a company decreases at a constant rate over time and grows by means of upward jumps, which occur at random times and sizes. It is said to have applications to companies with economical activities involved in research and development. This model is dual to the well-known Cramér-Lundberg risk model with applications to insurance. Most existing results on the study of the dual model assume that the random waiting times between consecutive gains follow an exponential distribution, as in the classical Cramér-Lundberg risk model. We generalize to other compound renewal risk models where such waiting times are Erlang(n) distributed. Using the roots of the fundamental and the generalized Lundberg's equations, we get expressions for the ruin probability and the Laplace transform of the time of ruin for an arbitrary single gain distribution. Furthermore, we compute expected discounted dividends, as well as higher moments, when the individual common gains follow a Phase-Type, PH(m), distribution. We also perform illustrations working some examples for some particular gain distributions and obtain numerical results.

TAYLOR, GREG. *Bayesian chain ladder models*. 75–99. The literature on Bayesian chain ladder

models is surveyed. Both Mack and cross-classified forms of the chain ladder are considered. Both cases are examined in the context of error terms distributed according to a member of the exponential dispersion family. Tweedie and over-dispersed Poisson errors follow as special cases. Bayesian cross-classified chain ladder models may randomise row, column or diagonal parameters. Column and diagonal randomisation has been largely absent from the literature until recently. The present paper allows randomisation of row and column parameters. The Bayes estimator, the linear Bayes (credibility) estimator, and the MAP estimator are shown to be identical in the Mack case, and in the cross-classified case provided that the error terms are Tweedie distributed. In the Mack case the variance structure is generalised considerably from the existing literature. In the cross-classified case the model structure differs somewhat from the existing literature, and a comparison is made between the two. MAP estimators for the cross-classified case are often given by implicit equations that require numerical solution. Recursive formulas are given

for these in the general case of error terms from the exponential dispersion family. The connection between the cross-classified case and Bornhuetter-Ferguson prediction is explored.

WILLMOT, GORDON E; WOO, JAE-KYUNG. *On some properties of a class of multivariate Erlang mixtures with insurance applications*. 151–173. We discuss some properties of a class of multivariate mixed Erlang distributions with different scale parameters and describes various distributional properties related to applications in insurance risk theory. Some representations involving scale mixtures, generalized Esscher transformations, higher-order equilibrium distributions, and residual lifetime distributions are derived. These results allows for the study of stop-loss moments, premium calculation, and the risk allocation problem. Finally, some results concerning minimum and maximum variables are derived and applied to pricing joint life and last survivor policies.

ZHOU, MING; YUEN, KAM C. *Portfolio selection by minimizing the present value of capital injection costs*. 207–238. This paper considers the portfolio selection and capital injection problem for a diffusion risk model within the classical Black-Scholes financial market. It is assumed that the original surplus process of an insurance portfolio is described by a drifted Brownian motion, and that the surplus can be invested in a risky asset and a risk-free asset. When the surplus hits zero, the company can inject capital to keep the surplus positive. In addition, it is assumed that both fixed and proportional costs are incurred upon each capital injection. Our objective is to minimize the expected value of the discounted capital injection costs by controlling the investment policy and the capital injection policy. We first prove the continuity of the value function and a verification theorem for the corresponding Hamilton-Jacobi-Bellman (HJB) equation. We then show that the optimal investment policy is a solution to a terminal value problem of an ordinary differential equation. In particular, explicit solutions are derived in some special cases and a series solution is obtained for the general case. Also, we propose a numerical method to solve the optimal investment and capital injection policies. Finally, a numerical study is carried out to illustrate the effect of the model parameters on the optimal policies.

ASTIN Bulletin

45(2), 2015

BÜHLMANN, HANS; MORICONI, FRANCO. *Credibility claims reserving with stochastic diagonal effects*. 309–353. An interesting class of stochastic claims reserving methods is given by the models with conditionally independent loss increments (CILI), where the incremental losses are conditionally independent given a risk parameter $\theta_{i,j}$ depending on both the accident year i and the development year j . The Bühlmann-Straub credibility reserving (BSCR) model is a particular case of a CILI model where the risk parameter is only depending on i . We consider CILI models with additive diagonal risk (ADR), where the risk parameter is given by the sum of two components, one depending on the accident year i and the other depending on the calendar year $t = i + j$. The model can be viewed as an extension of the BSCR model including random diagonal effects, which are often declared to be important in loss reserving but rarely are specifically modelled. We show that the ADR model is tractable in closed form, providing credibility formulae for the reserve and the mean square error of prediction (MSEP). We also derive unbiased estimators for the variance parameters which extend the classical Bühlmann-Straub estimators. The results are illustrated by a numerical example and the estimators are tested by simulation. We find that the inclusion of random diagonal effects can be significant for the reserve estimates and, especially, for the evaluation of the MSEP.

The paper is written with the purpose of illustrating the role of stochastic diagonal effects. To isolate these effects, we assume that the development pattern is given. In particular, our MSEP values do not include the uncertainty due to the estimation of the development pattern.

CATHCART, MARK J; LOK, HSIAO YEN; MCNEIL, ALEXANDER J; MORRISON, STEVEN. *Calculating variable annuity liability “Greeks” using Monte Carlo simulation.* 239–266. The implementation of hedging strategies for variable annuity products requires the calculation of market risk sensitivities (or “Greeks”). The complex, path-dependent nature of these products means that these sensitivities are typically estimated by Monte Carlo methods. Standard market practice is to use a “bump and revalue” method in which sensitivities are approximated by finite differences. As well as requiring multiple valuations of the product, this approach is often unreliable for higher-order Greeks, such as gamma, and alternative pathwise (PW) and likelihood-ratio estimators should be preferred. This paper considers a stylized guaranteed minimum withdrawal benefit product in which the reference equity index follows a Heston stochastic volatility model in a stochastic interest rate environment. The complete set of first-order sensitivities with respect to index value, volatility and interest rate and the most important second-order sensitivities are calculated using PW, likelihood-ratio and mixed methods. It is observed that the PW method delivers the best estimates of first-order sensitivities while mixed estimation methods deliver considerably more accurate estimates of second-order sensitivities; moreover there are significant computational gains involved in using PW and mixed estimators rather than simple BnR estimators when many Greeks have to be calculated.

CHEN, AN; DELONG, LUKASZ. *Optimal investment for a defined-contribution pension scheme under a regime switching model.* 397–419. We study an asset allocation problem for a defined-contribution (DC) pension scheme in its accumulation phase. We assume that the amount contributed to the pension fund by a pension plan member is coupled with the salary income which fluctuates randomly over time and contains both a hedgeable and non-hedgeable risk component. We consider an economy in which macroeconomic risks are existent. We assume that the economy can be in one of I states (regimes) and switches randomly between those states. The state of the economy affects the dynamics of the tradeable risky asset and the contribution process (the salary income of a pension plan member). To model the switching behaviour of the economy we use a counting process with stochastic intensities. We find the investment strategy which maximizes the expected exponential utility of the discounted excess wealth over a target payment, e.g. a target lifetime annuity.

RADUCAN, ANISOARA MARIA; VERNIC, RALUCA; ZBAGANU, GHEORGHITA. *Recursive calculation of ruin probabilities at or before claim instants for non-identically distributed claims.* 421–443. In this paper, we present recursive formulae for the ruin probability at or before a certain claim arrival instant for some particular continuous time risk model. The claim number process underlying this risk model is a renewal process with either Erlang or a mixture of exponentials inter-claim times (ICTs). The claim sizes (CSs) are independent and distributed in Erlang’s family, i.e., they can have different parameters, which yields a non-homogeneous risk process. We present the corresponding recursive algorithm used to evaluate the above mentioned ruin probability and we illustrate it on several numerical examples in which we vary the model’s parameters to assess the impact of the non-homogeneity on the resulting ruin probability.

RIEGEL, ULRICH. *A quantitative study of chain ladder based pricing approaches for long-tail quota shares.* 267–307. Pricing approaches for long-tail quota shares are often based on the chain ladder method. Apart from IBNR calculation, common pricing methods require volume measures

for accident years in the observation period, and for the quotation period. In practice, in most cases restated premiums are used as the volume measures. The prediction error of the chain ladder method is an important part of the prediction uncertainty of these pricing approaches. There are, however, two sources of uncertainty that are not addressed by the chain ladder model: the stochastic volatility of the claims in the first development year; and the restatement uncertainty, the risk that the restated premium is not a good volume measure. We extend Mack's chain ladder model to cover these two sources of uncertainty, and calculate the mean-squared error of chain ladder pricing approaches with arbitrary weights for the accident years in the observation period. Then we focus on the problem of finding optimal weights for the accident years. First, we assume that the parameters for restatement uncertainty are given, and provide recursion formulas to calculate approximately-optimal weights. Second, we describe a maximum likelihood approach that can be used to estimate the restatement uncertainty.

SIU, CHI CHUNG; YAM, SHEUNG CHI PHILLIP; YANG, HAILIANG. *Valuing equity-linked death benefits in a regime-switching framework*. 355–395. In this article, we consider the problem of computing the expected discounted value of a death benefit, e.g. in Gerber *et al.* (2012, 2013), in a regime-switching economy. Contrary to their proposed discounted density approach, we adopt the Laplace transform to value the contingent options. By this alternative approach, closed-form expressions for the Laplace transforms of the values of various contingent options, such as call/put options, lookback options, barrier options, dynamic fund protection and the dynamic withdrawal benefits, have been obtained. The value of each contingent option can then be recovered by the numerical Laplace inversion algorithm, and this efficient approach is documented by several numerical illustrations. The strength of our methodology becomes apparent when we tackle the valuations of exotic contingent options in the cases when (1) the contracts have a finite expiry date; (2) when the time-until-death variable is uniformly distributed in accordance with De Moivre's law.

YANG, JINGPING; CHEN, ZHIJIN; WANG, FANG; WANG, RUODU. *Composite Bernstein copulas*. 445–475. Copula function has been widely used in insurance and finance for modelling inter-dependency between risks. Inspired by the Bernstein copula put forward by Sancetta and Satchell (2004, *Econometric Theory*, 20, 535–562), we introduce a new class of multivariate copulas, the composite Bernstein copula, generated from a composition of two copulas. This new class of copula functions is able to capture tail dependence, and it has a reproduction property for the three important dependency structures: comonotonicity, countermonotonicity and independence. We introduce an estimation procedure based on the empirical composite Bernstein copula which incorporates both prior information and data into the estimation. Simulation studies and an empirical study on financial data illustrate the advantages of the empirical composite Bernstein copula estimation method, especially in capturing tail dependence.

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Australian Journal of Actuarial Practice

3, 2015

ADAMIC, PETER. *Life expectancy improvement with a cure distribution for a cause of death*. 59–61. In many circumstances, the increase in life expectancy when a certain cause of death is eliminated is sought. Traditionally, these calculations have been based on the assumption that the cause in question is simply omitted, which is equivalent to the cause being taken out of consideration, from the outset, with certainty. In this paper, we propose continuous and discrete models whereby a probability distribution for the cure of a specific cause of death over time can be incorporated so as to more accurately predict the increase in life expectancy. The theoretical results are applied to a real data set involving HIV-related deaths from the State of Colorado, United States of America, between the years 2000 and 2012.

ASHER, ANTHONY. *Retirement incomes – issues and next steps*. 93–97. The Actuaries Institute has made the development of an appropriate retirement incomes market a major policy priority. It is therefore pleasing to see how the issue has been picked up by the Financial Systems Inquiry (FSI) Final Report, 1 and by many others in government and industry. As the FSI summarises: The superannuation drawdown phase of Australia’s retirement income system provides limited choice for managing risk in retirement. It also gives little guidance to retirees in navigating complex and important financial decisions. Retirees do not efficiently convert superannuation benefits into income streams in retirement. This note mentions some recent developments, and sets out a view on priorities for the years ahead. Although I am convenor of the Institute’s Retirement Incomes Working Group (RIWG), the views expressed here are personal.

BROWNE, BRIDGET. *Recent Australian insured lives mortality: a review of the Actuaries Institute – Financial Services Council 2004–2008 Lump Sum Graduation*. 99–106. In 2012 the Graduation Taskforce of the Actuaries Institute published a report “Graduation of the 2004–2008 Lump Sum Investigation Data”. This is now the most recent publicly available report on Australian insured lives’ mortality experience. The tables in that report are compared with, on the one hand, contemporary Australian population mortality, and on the other, the preceding Australian insured lives tables, IA95-97. Thus the paper reports and comments on the level of insured lives’ mortality compared with that of the total population as well as changes in both of these over the period from 1996 to 2006. It appears that insured lives mortality has improved less than population mortality over the 10 years.

CUMPSTON, RICHARD; SARJEANT, HUGH; SERVICE, DAVID. *Estimates of individual life expectancies*. 35–46. Estimates of individual life expectancies require assumptions about future causes of death, and allowances for socio-economic factors. Deaths from circulatory diseases, cancers, respiratory diseases and external causes were 75% of deaths in Australia in 2012. All have shown continuing downwards trends since 1986. Reported deaths from the next three major causes of death have all increased. Expert advice is needed to understand the reasons for past changes, and to make reasonable assumptions about future deaths from each cause. Unmarried persons have higher mortality rates than the married. Recent Danish data show that lone persons

are more likely to die from cardiovascular disease, respiratory disease and suicide. Australian data show that lone persons are more likely to have mental disorders and nervous system diseases, and disabilities arising from external causes. UK data show that persons in unskilled occupations have higher mortality rates. The paper proposes the use of macro-models to approximately replicate past changes in causes of death, and the use of microsimulation to validate assumed relationships between socio-economic variables and diseases.

FERRIS, SHAUNA; PARR, NICK; MARKEY, RAY; KYNG, TIM. *Long service leave: past, present and future*. 5–22. As a result of changes to the Australian industrial relations framework, long service leave benefits are under review. State and Commonwealth governments are working towards the development of a new national standard for long service leave (LSL). It is, therefore, timely to re-examine the purpose of LSL. How do people use their LSL benefits? What are the main benefits of LSL for employers, employees, and the community as a whole? This paper provides a historical overview of developments, as well as a summary of current trends, and discusses some proposals for improved vesting and portability of benefits.

FERRIS, SHAUNA. *Repercussions: the impact of the AIG crisis on its insurance subsidies*. 71–91. Numerous studies have shown that insurance companies can be adversely affected by problems at a parent company or an affiliate – indeed, over the years, affiliate-related problems have been severe enough to cause the insolvency of many insurance companies. This paper provides a case study of affiliate risk, based on the experience of insurance companies that were part of the American International Group, Inc (AIG) during the global financial crisis of 2007/08. This case study raises many questions about the effectiveness of risk management and prudential supervision of large, complex, financial conglomerates.

O'MEARA, TALEITHA; SHARMA, AAKANSHA; BRUHN, AARON. *Australia's piece of the puzzle – why don't Australians buy annuities?* 47–57. An individual who purchases a lifetime annuity is guaranteed to receive an income for life. As such this purchase would confer protection against investment and longevity risk for the individual in retirement. Despite these advantages, annuity sales in voluntary markets generally remain low. Reasons for this state of affairs from the current literature are reviewed, and further reasons particular to the Australian context are suggested. This contributes to an understanding of the factors that underlie the lack of popularity in contexts other than Australia as well.

TANG, CHEN; BROWNE, BRIDGET; BRUHN, AARON. *Valuing annuities based on alternative mortality projections*. 23–33. Future mortality is a key component when pricing longevity-based products such as annuities. Estimating future mortality is, however, a significant challenge, with a range of approaches adopted by various users to date. We describe the recent developments in mortality projections that have arisen from the UK Institute and Faculty of Actuaries' Continuous Mortality Investigation (CMI), and apply this method to Australian mortality data. Projected mortality under this approach is used to calculate values for both immediate and deferred life annuities, and is compared with values arising from other mortality projections for Australia. Our results are noticeably similar to other projection approaches, in particular those of Tickle and Booth (2014) [Tickle, L, & Booth, H, The longevity prospects of Australian seniors: an evaluation of forecast method and outcome, Asia Pacific, *Journal of Risk and Insurance* (2014) 8(2): 259–92] and the Productivity Commission (2013) [Productivity Commission (Australia), *An ageing Australia: preparing for the future*, Government of Australia, 2013]. Sensitivity analyses are also presented. It is apparent that an embedded and ongoing practice of effective risk management,

rather than the mere pursuit of a more “accurate” picture of future mortality, is key to managing longevity exposure.

VAN WYK, BRNIC. *Age pension indexation*. 107–115. This note focuses on one of the proposed changes in particular – the change in indexation (and “benchmarking”) of the Age Pension – and aims to highlight the long-term impact that this policy change may have on retirees - extract from Introduction.

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European Actuarial Journal

5(1), 2015

CHEN, AN; CLEVER, SIMONA. *Optimal supervisory rules for pension funds under diverse pension security mechanisms*. 29–53. The present paper analyzes optimal supervisory rules for pension funds taking account of diverse pension security mechanisms: support provided by either a plan sponsor, a pension guarantee fund or by both. Assuming that the regulatory rule is either to control the shortfall probability or expected shortfall, we show that both the security mechanisms and risk measures used by the regulators have a substantial impact on the optimal regulation and hence need to be considered adequately when setting regulatory rules.

FRÖHLICH, ANDREAS; WENG, ANNEGRET. *Modelling parameter uncertainty for risk capital calculation*. 79–112. For risk capital calculation within the framework of Solvency II the possible loss of basic own funds over the next business year of an insurance undertaking is usually interpreted as a random variable X . If we assume that the parametric distribution family $\{X(\theta) \mid \theta \in I \subseteq \mathbb{R}^d\}$ is known, but the parameter θ is unknown and has to be estimated from the available historical data, the undertaking faces parameter uncertainty. To assess methods to model parameter uncertainty for risk capital calculations we apply a criterion going back to the theory of predictive inference which has already been used in the context of Solvency II. In particular, we show that the bootstrapping approach is not appropriate to model parameter uncertainty from the undertaking’s perspective. Based on ideas closely related to the concept of fiducial inference we introduce a new approach to model parameter uncertainty. For a wide class of distributions and for common estimators including the maximum likelihood method we prove that this approach is appropriate to model parameter uncertainty according to the criterion mentioned above. Several examples demonstrate that our method can easily be applied in practice.

GOFFARD, PIERRE-OLIVIER; GUERRAULT, XAVIER. *Is it optimal to group policyholders by age, gender, and seniority for BEL computations based on model points?* 165–180. An aggregation method adapted to life insurance portfolios is presented. We aim at optimizing the computation time when using Monte Carlo simulations for best estimate liability calculation. The method is a two-step procedure. The first step consists in using statistical partitioning methods in order to gather insurance policies. The second step is the construction of a representative policy for each aforementioned groups. The efficiency of the aggregation method is illustrated on a real

saving contracts portfolio within the frame of a cash flow projection model used for best estimate liabilities and solvency capital requirements computations. The procedure is already part of AXA France valuation process.

HAPP, SEBASTIAN; MERZ, MICHAEL; WÜTHRICH, MARIO V. *Best-estimate claims reserves in incomplete markets*. 55–77. We give a rigorous definition of best-estimates reserves for insurance liabilities in a general multiperiod financial market setting. In this general multiperiod financial market setting we describe payoff spaces and optimal dynamic hedging strategies. Based on this optimal dynamic hedging strategies we define best-estimate reserves for insurance liabilities. One crucial observation is that we need the notion of optimal hedging and state-price deflators because there does not necessarily exist an equivalent probability measure under which best-estimate reserves can be calculated.

HIEBER, PETER; KORN, RALF; SCHERER, MATTHIAS. *Analyzing the effect of low interest rates on the surplus participation of life insurance policies with different annual interest rate guarantees*. 11–28. We analyze the effects of a prevailing low interest rates regime on investment decisions of insurance companies and on the risk/return profile of participating life insurance policies with different contractually guaranteed minimum annual return. Our analysis is based on German legislation and a stylized insurance company with two cohorts of insured persons having different minimal return guarantees. Our findings shed some light on the non-trivial interrelation between profit distribution, minimum guarantees, and resulting profitability for the different cohorts. Moreover, we investigate the complex role of the risk reserve that allows insurance companies to redistribute profits in time and, less obviously, also between the cohorts.

KREER, MARKUS; KIZILERSÜ, AYSE; THOMAS, ANTHONY W; EGÍDIO DOS REIS, ALFREDO D. *Goodness-of-fit tests and applications for left-truncated Weibull distributions to non-life insurance*. 139–163. In risk theory with application to insurance, the identification of the relevant distributions for both the counting and the claim size processes from given observations is of major importance. In some situations left-truncated distributions can be used to model, not only the single claim severity, but also the inter-arrival times between two consecutive claims. We show that left-truncated Weibull distributions are particularly relevant, especially for the claim severity distribution. For that, we first demonstrate how the parameters can be estimated consistently from the data, and then show how a Kolmogorov-Smirnov goodness-of-fit test can be set up using modified critical values. These critical values are universal to all left-truncated Weibull distributions, independent of the actual Weibull parameters. To illustrate our findings we analyse three applications using real insurance data, one from a Swiss excess of loss treaty over automobile insurance, another from an American private passenger automobile insurance and a third from earthquake inter-arrival times in California.

LEMAIRE, JEAN; PARK, SOJUNG CAROL; WANG, KILI C. *The impact of covariates on a bonus–malus system: an application of Taylor’s model*. 1–10. Obviously, the design of a bonus–malus system has to take into consideration all rating variables used by the auto insurance carrier. For instance, a single male urban driver is likely to be penalized twice, a priori through explicit surcharges linked to his risk class, and a posteriori through premium increases triggered by the transition rules of the bonus–malus system, creating the possibility of excessive premiums through double-counting for the same reason. Taylor (*ASTIN Bulletin* (1997) 27:319–327) developed a Bayesian model to evaluate the impact of covariate rating variables on bonus–malus premium levels, but could not access actual data to implement his model. We present the first real-life application of Taylor’s research, by using a unique database originating from Taiwan and the

bonus-malus system in force in this island. Our data combines car and insurance information from the leading insurer in the island with annual mileage readings from a network of repair shops operated by the largest car manufacturer – over a quarter million policy-years. Park *et al.* (The use of annual mileage as a rating variable. Working paper, 2014), using the same data, used negative binomial regression to prove that mileage is by far the best predictor of accidents. The application of Taylor's model concludes that the impact of mileage on bonus–malus premium levels is small. Therefore, double-counting should not be considered as a major concern in practice.

QUIJANO XACUR, OSCAR ALBERTO; GARRIDO, JOSÉ. *Generalised linear models for aggregate claims: to Tweedie or not?* 181–202. The compound Poisson distribution with gamma claim sizes is a very common model for premium estimation in Property and Casualty insurance. Under this distributional assumption, generalised linear models (GLMs) are used to estimate the mean claim frequency and severity, then these estimators are simply multiplied to estimate the mean aggregate loss. The Tweedie distribution allows to parametrise the compound Poisson-gamma (CPG) distribution as a member of the exponential dispersion family and then fit a GLM with a CPG distribution for the response. Thus, with the Tweedie distribution it is possible to estimate the mean aggregate loss using GLMs directly, without the need to previously estimate the mean frequency and severity separately. The purpose of this educational note is to explore the differences between these two estimation methods, contrasting the advantages and disadvantages of each.

SHAO, JIA; PANTELOUS, ATHANASIOS A; PAPAIOANNOU, APOSTOLOS D. *Catastrophe risk bonds with applications to earthquakes.* 113–138. Catastrophe (CAT) risk bonds provide a solid mechanism for direct transfer of the financial consequences of extreme events (hazards) into the financial market. During the past two decades, insurance companies have been searching for more adequate liquidity funds as a consequence of increasing losses due to climate change and severe natural disasters. The aims of this study were twofold. First, we study the pricing process for CAT bonds for the structure of n financial and m catastrophe-independent risks. Second, to illustrate the applicability of our results, an application for earthquakes is considered using extreme value theory. As a numerical example, a CAT bond with historical data from California is proposed in which the magnitude, latitude, longitude, and depth are included in the model. In addition, appropriate models are constructed for the term structure of interest and inflation rate dynamics, and a stochastic process for the coupon rate. Finally, on the basis of analysis for the aforementioned catastrophe and financial market risks, we can use equilibrium pricing theory to find a certain value price for the CAT California earthquake bond.

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Geneva Papers on Risk and Insurance

40(1), 2015

ACHARYYA, MADHUSUDAN; SECKER, JENNY. *Why choose an insurance career? A pilot study of university students' preferences regarding the insurance profession.* 108–130. The study investigates the most relevant factors affecting business students' choice of a career in the

insurance industry. Recent industry surveys indicate that students find the insurance profession uninteresting and so are reluctant to pursue a career within it. However, many of the survey respondents showed an interest in the profession. We tested three hypotheses to determine whether student choices are affected by environmental, opportunity and awareness factors. The study applied structural equation modelling and regression analysis to the data and finds that nationality, together with other environmental factors, significantly affects their choice of the insurance profession. In addition, we found that students are unaware of the underlying philosophy of insurance businesses, their products and their vital role in the economic and social system. The lack of adequate research, education providers, and the shortage of study materials and inadequate marketing strategies are among the key causes of students' reluctance to engage with the insurance profession. This study may assist insurers, educators and professional bodies to develop their strategy directed towards attracting talents to the insurance industry.

BIENER, CHRISTIAN; ELING, MARTIN; HENDRIK WIRFS, JAN. *Insurability of cyber risk: an empirical analysis*. 131–158. This paper discusses the adequacy of insurance for managing cyber risk. To this end, we extract 994 cases of cyber losses from an operational risk database and analyse their statistical properties. Based on the empirical results and recent literature, we investigate the insurability of cyber risk by systematically reviewing the set of criteria introduced by Berliner (1982) [Berliner, B. (1982) *Limits of insurability of risks*, Englewood Cliffs, NJ: Prentice-Hall, 1982]. Our findings emphasise the distinct characteristics of cyber risks compared with other operational risks and bring to light significant problems resulting from highly interrelated losses, lack of data and severe information asymmetries. These problems hinder the development of a sustainable cyber insurance market. We finish by discussing how cyber risk exposure may be better managed and make several suggestions for future research.

CARAYANNOPOULOS, PETER; PEREZ, M FABRICIO. *Diversification through catastrophe bonds: lessons from the subprime financial crisis*. 1–28. Are catastrophe bonds (CAT bonds) zero-beta investments? Are they a valuable new source of diversification for investors? We study these questions by analysing the dynamic relations of CAT bond returns and the returns of the stock, corporate bond and government bond markets. Our multivariate GARCH model results provide evidence that CAT bonds are zero-beta assets only in non-crisis periods. We document that CAT bonds were not immune to the effects of the recent financial crisis. With the collapse of Lehman Brothers, CAT bond returns became significantly correlated with the market. However, the relatively small effect of the crisis on CAT bonds compared with other asset classes make them a valuable source of diversification for investors. Finally, it seems that the improved structures for new CAT bonds issued since 2009 have been positively received by the market, as CAT bond betas returned to pre-crisis levels.

DREASSI, ALBERTO; SCHNEIDER, MARIA CLAUDIA. *Bancassurance and scale economies: evidence from Italy*. 89–107. Integration between banks and insurers is a widely investigated trend in financial markets. Despite heterogeneity of bancassurance across countries, the financial crisis is reshaping both intermediaries and customers' demand. Although previous research provides evidence of economies of scale in bancassurance, we add to this literature by investigating differences due to alternative ownership models over an extended period (1998–2012) and testing for the effects of the financial crisis through a translog cost function. We focus on the Italian market, where bancassurance plays a major role and all ownership models are present. We find that the cost function changed significantly after 2007 as new unexploited scale economies emerged, especially for independent insurers that showed earlier optimal returns to scale.

More integrated groups, despite a remarkable difference in their trend for total costs, diverge in a similar fashion from independent insurers in terms of scale economies.

DUMM, RANDY E; JOHNSON, MARK A; WATSON, CHARLES C, JR. *An examination of the geographic aggregation of catastrophic risk*. 159–177. The debate in the United States about establishing a mechanism for insuring catastrophic wind risk at the national level pre-dates the intense 2004–2005 hurricane seasons. The prevailing argument against establishing any larger risk pool is that it would create a subsidy for the higher risk exposures. To determine whether benefits do accrue by aggregating catastrophic risk across increasingly wide geographic areas, the paper uses catastrophe models to evaluate the behaviour of residential property portfolios within the state of Florida and for a larger risk pool that includes multiple combinations of coastal states in the south eastern United States. We find that geographic aggregation does not inherently subsidise high-risk exposures, reduces uncertainty, and reduces required reserves relative to total exposure for the least frequent and more severe events. This finding holds true for all state combinations evaluated in this study.

LAI, YI-HSUN; WEN, MIN-MING; WANG, CHIEN-PO. *Regulatory forbearance and the failure cost for U.S. property and liability insurers*. 66–88. This study examines the extent to which regulatory forbearance can affect the fragility of U.S. property and liability (P/L) insurance firms. By using a split-population survival model, we find that the risk-based capital (RBC) ratio is inversely correlated with the resolution cost paid by guaranty funds but is uncorrelated with the insurer failure rate. This implies that the RBC regulatory rules may embed some extent of forbearance that can lead to greater failure costs when insurers become insolvent. The policy implication of this study is that regulators should pay more attention to controlling failure costs by adopting more flexible intervention rules rather than merely focusing on forestalling insolvencies. Our empirical results also support the view that greater regulatory separation can reduce the insurer failure rate, while more stringent rate regulation can make insurers more fragile.

RAUCH, JAMES; WENDE, SABINE. *Solvency prediction for property-liability insurance companies: evidence from the financial crisis*. 47–65. The financial crisis of 2008 generated sizeable losses in the financial sector around the world. Because regulators are used for predicting insurers' financial strength in order to detect financially distressed firms as early as possible, we question how reliably regulators can forecast financial strength, especially during a financial crisis. We use the company-level data of German property-liability insurers from 2004 to 2011 to examine factors that affect the insurer's regulatory solvency ratio. Furthermore, we develop a prediction model to classify the insurers regarding their financial strength. We show that, in particular, the lagged solvency ratio can be used to predict the future regulatory solvency ratio irrespective of the economic conditions. Thus, our results imply that German regulators are able to detect insurers in financial distress early enough to take appropriate actions to protect policyholders' interests. Our results do not support the adoption of tighter regulations or higher capital requirements.

YAN, ZHIQIANG; HONG, LIANG. *Testing for asymmetric information in reinsurance markets*. 29–46. Empirical studies on asymmetric information have mainly focused on primary insurance markets, but comparatively little attention has been given to reinsurance markets. This study investigates the existence of asymmetric information by testing for a positive correlation between coverage and ex post risk in three major reinsurance markets for the period 1995–2000 and finds that (1) asymmetric information problems are present in the private passenger auto liability and homeowners reinsurance markets, but not in the product liability reinsurance market; (2) retention

limits are widely utilised to mitigate asymmetric information problems; (3) long-term contracting relationships are either rarely used or not effective in controlling asymmetric information problems.

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BOYER, M MARTIN; OWADALLY, IQBAL. *Underwriting apophenia and cryptids: are cycles statistical figments of our imagination?* 232–255. This paper re-examines the evidence in favour of the existence of underwriting cycles in property and casualty insurance and their economical significance. Using a meta-analysis of published papers in the area of insurance economics, we show that the evidence supporting the existence of underwriting cycles is misleading. There is, in fact, little evidence in favour of insurance cycles with a linear autoregressive character. This means that any cyclicalities in firm profitability in the property and casualty insurance industry is not predictable in a classical econometric framework. It follows that pricing in the property and casualty insurance industry is not incompatible with that of a competitive market.

KRAUT, GUNTHER; RICHTER, ANDREAS. *Insurance regulation and life catastrophe risk: treatment of life catastrophe risk under the SCR standard formula of Solvency II and the necessity of partial internal models.* 256–278. The regulatory regime in Europe is undergoing a fundamental change that will serve as a benchmark for the regulators in other countries. This paper analyses the influence of regulation imposed by Solvency II on life catastrophe risk management activities. The interplay of extreme mortality risks and risk management activities is demonstrated, and the special characteristics of different causes of life catastrophe risk are identified. The advice of the Committee of European Insurance and Occupational Pensions Supervisors, now the European Insurance and Occupational Pensions Authority, regarding the life catastrophe risk sub-module of the solvency capital requirement standard formula is to apply a unified single mortality catastrophe shock scenario. We show that this approach does not properly reflect life catastrophe risk and that it potentially prevents the recognition of more sophisticated risk management instruments for the solvency capital requirement calculation. As a result of this analysis, proposals are made for how these shortcomings can be resolved by using a simple generic partial internal model. This model facilitates the recognition of non-proportional risk transfer techniques and thus provides incentives for their use. We show that these proposals are in line with and relevant to the current trend towards the potential development of a more liquid market for extreme mortality risks.

LIANG, HSIN-YU; CHING, YANN PENG. *Suggestions for bancassurance markets in China: implications from European countries.* 279–294. This study discusses the operational benefits of integration of the banking and insurance sub-sectors in Europe to formulate policy recommendations for the bancassurance markets in an emerging country, China. When the financial integration of banking and insurance services began in European countries in the 1990s, most banks and insurance companies had already been listed for some time. Thus, we use the monthly stock returns of banks and insurance companies that had not yet been integrated as of 2008 to examine efficient frontier portfolio and pairwise combinations in European bancassurance markets. We find that portfolio diversification is an important benefit of banks integrating with different types of insurance companies. Consistent with the literature, we further show that banks strategically involved in non-life insurance will benefit in terms of enhanced returns and reduced risks. Our results present implications for building a bancassurance market in China.

MICHEL-KERJAN, ERWANN; CZAJKOWSKI, JEFFREY; KUNREUTHER, HOWARD C. *Could flood insurance be privatised in the United States? A primer.* 179–208. Since 1968, homeowners' flood insurance in the United States has been mainly provided through the federally-run National Flood Insurance Program (NFIP). The Flood Insurance Reform Act of 2012 raises the possibility of moving coverage to the private sector, assuming the market can price this risk effectively and that premiums reflect risk. This paper provides the first large-scale quantification of risk-based premiums for over 300,000 residences prone to either storm surge or inland flooding using commercially developed probabilistic catastrophe models, and compares these premiums with those currently charged by the NFIP. Our findings reveal significant differences between the two. In some areas, the NFIP charges prices that are more than 15 times the pure premium, while other areas are charged up to three times less than the pure premium. The paper discusses the market and policy implications of these findings.

PAKDEL-LAHIJ, NAGHMEH; HOCHRAINER-STIGLER, STEFAN; GHAFORY-ASHTIANY, MOHSEN; SADEGHI, MEHDI. *Consequences of financial vulnerability and insurance loading for the affordability of earthquake insurance systems: evidence from Iran.* 295–315. Many governments provide financial assistance for reconstruction of damaged housing units after a disaster in order to prevent vulnerable households from falling into poverty traps or entering low growth cycles. To lessen these risks and the overall financial burden on the public sector after extreme events, private insurance schemes provide one viable solution. In this paper, the possible effects of such solutions are assessed for District 1 of Shiraz, Iran, based on recent probabilistic earthquake risk modelling. The work explicitly focuses on the financial vulnerability of different household groups as well as possible increases in premiums due to uncertainties in the underlying risk model through the use of loading factors. The results are compared with current non-probabilistic-based premiums that are used by most insurance companies in Iran, and recommendations are given as to which schemes may fit best or could be affordable for society to manage future earthquake risks.

SHIU, YUNG-MING. *What determines Lloyd's market syndicates' unsolicited ratings?* 316–333. Based upon a sample of Lloyd's syndicates covering the years 2006–2010, we examine the determinants of (i) the likelihood of being rated and (ii) the rating that is likely to be assigned by Standard and Poor's, from which we document evidence of selectivity bias. Larger, more profitable and liquid syndicates are found to be more likely to receive a rating, and indeed, to have higher ratings. Syndicates with more reinsurance dependence are more likely to be rated, but less likely to obtain a higher rating. Our findings indicate that the "signalling" hypothesis dominates the "uncertainty reduction" theory.

TSENG, LU-MING; KANG, YUE-MIN. *Managerial authority, turnover intention and medical insurance claims adjusters' recommendations for claim payments.* 334–352. Although it is acknowledged that the final decision of whether to accept or reject a medical claim application is determined by medical insurance claims adjusters, very little research on insurance fraud has considered the factors that contribute to the unjustified claim decisions made by these professionals. The purpose of this study is to examine the impacts of managerial authority and moral intensity on medical insurance claims adjusters' decision-making in the claims handling process. Whether or not a medical insurance claims adjuster with higher turnover intention will propose more lenient recommendations for claim payments is also addressed. The research hypotheses were tested by using a survey. One hundred and thirty full-time Taiwanese medical insurance claims adjusters participated in the investigation. The results show that managerial authority is the

strongest predictor of the medical insurance claims adjusters' final recommendation for insurance claim payment.

ZIMMERMANN, JOCHEN; VEITH, STEFAN; SCHYMCZYK, JOHANNES. *Measuring risk premiums using financial reports and actuarial disclosures*. 209–231. Insurance companies increasingly augment their financial reports by releasing actuarial measures – the so-called embedded value – to supply information about the value of their life insurance activities. Both accounting and actuarial measures differ with respect to the timeliness of profit realisation and its reliability, and their performance in yielding information may differ. This paper asks if and how embedded values help in assessing risk premiums. We estimate multifactor market models in the spirit of Fama and French, and find that actuarial disclosures are superior to financial accounting in estimating these risk premiums. They further add information to financial reports as an estimator for growth opportunities.

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FEDELE, ALESSANDRO; TEDESCHI, PIERO. *Quality of after-sales services in a competitive insurance sector*. 65–88. This paper tackles the issue of unverifiable quality of after-sales insurance services, such as a prompt reimbursement of damages. A dynamic model is introduced in order to allow reputation to emerge as a means of disciplining insurance firms to deliver high quality. The equilibrium of a repeated Bertrand game among the insurers is analysed and conditions are derived under which more concentration in the insurance industry can lead to greater equilibrium consumer welfare.

FISCHER, KATHARINA; SCHLÜTTER, SEBASTIAN. *Optimal investment strategies for insurance companies when capital requirements are imposed by a standard formula*. 15–40. The Solvency II standard formula employs an approximate value-at-risk approach to define risk-based capital requirements. This paper investigates how the standard formula's stock risk calibration influences the equity position and investment strategy of a shareholder-value-maximising insurer with limited liability. The capital requirement for stock risks is determined by multiplying a regulation-defined stock risk parameter by the value of the insurer's stock portfolio. Intuitively, a higher stock risk parameter should reduce risky investments as well as insolvency risk. However, we find that the default probability does not necessarily decrease when reducing the investment risk (by increasing the stock risk parameter). We also find that, depending on the precise interaction between assets and liabilities, some insurers will invest conservatively, whereas others will prefer a very risky investment strategy, and a slight change of the stock risk parameter may lead from a conservative to a high-risk asset allocation.

GRISLAIN-LETRÉMY, CÉLINE; LEMOYNE DE FORGES, SABINE. *The benefits of uniform flood insurance*. 41–64. Prevention policies against flood, such as dams or levees, are commonly

designed by local jurisdictions and for most, they exert externalities on neighbouring jurisdictions. We study a model in which each jurisdiction chooses its collective prevention effort depending on the flood risk and on the insurance system that covers its inhabitants. As compulsory uniform insurance depends on all insureds' risk, it enables partial integration of prevention externalities by jurisdictions. We determine under which conditions compulsory uniform insurance Pareto dominates risk-rated insurance.

SCHLESINGER, HARRIS. *Lattices and lotteries in apportioning risk*. 1–14. Although risk aversion has been used in economic models for over 275 years, the past few decades have shown how higher order risk attitudes are also quite important. A behavioural approach to defining such risk attitudes was developed by Eeckhoudt and Schlesinger, based on simple lottery preference. This article shows how the mathematics of lattice theory can be used to model these lottery preferences. In addition to modelling a simple lattice structure, I show how such lattices can be extended in order to develop a better understanding of higher order risk attitudes.

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ASIMIT, ALEXANDRU V; CHEN, YIQING. *Asymptotic results for conditional measures of association of a random sum*. 11–18. Asymptotic results are obtained for several conditional measures of association. The chosen random variables are the first two order statistics and the total sum within a random sum. Many of the results have confirmed the “one-jump” property of the risk model. Non-trivial limits are obtained when the dependence among the first two order statistics is considered. Our results help in understanding the extreme behaviour of well-known reinsurance treaties that involve only few large claims. Interestingly, the Pearson product-moment correlation coefficient between the first two order statistics provides an alternative procedure to estimate the tail index of the underlying distribution.

BALBÁS, ALEJANDRO; BALBÁS, BEATRIZ; BALBÁS, RAQUEL; HERAS, ANTONIO. *Optimal reinsurance under risk and uncertainty*. 61–74. This paper deals with the optimal reinsurance problem if both insurer and reinsurer are facing risk and uncertainty, though the classical uncertainty free case is also included. The insurer and reinsurer degrees of uncertainty do not have to be identical. The decision variable is not the retained (or ceded) risk, but its sensitivity with respect to the total claims. Thus, if one imposes strictly positive lower bounds for this variable, the reinsurer moral hazard is totally eliminated. Three main contributions seem to be reached. Firstly, necessary and sufficient optimality conditions are given in a very general setting. Secondly, the optimal contract is often a bang-bang solution, i.e., the sensitivity between the retained risk and the total claims saturates the imposed constraints. Thirdly, the optimal reinsurance problem is

equivalent to other linear programming problem, despite the fact that risk, uncertainty, and many premium principles are not linear. This may be important because linear problems may be easily solved in practice, since there are very efficient algorithms.

BOHNERT, ALEXANDER; GATZERT, NADINE; JØRGENSEN, PETER LØCHTE. *On the management of life insurance company risk by strategic choice of product mix, investment strategy and surplus appropriation schemes.* 83–97. The aim of this paper is to analyze the impact of management's strategic choice of asset and liability composition in life insurance on shortfall risk and the shareholders' fair risk charge. In contrast to previous work, we focus on the effectiveness of management decisions regarding the product mix and the riskiness of the asset side under different surplus appropriation schemes. We propose a model setting that comprises temporary life annuities and endowment insurance contracts. Our numerical results show that the effectiveness of management decisions in regard to risk reduction strongly depends on the surplus appropriation scheme offered to the customer and their impact on guaranteed benefit payments, which thus presents an important control variable for the insurer.

CECI, CLAUDIA; COLANERI, KATIA; CRETAROLA, ALESSANDRA. *Hedging of unit-linked life insurance contracts with unobservable mortality hazard rate via local risk-minimization.* 47–60. In this paper we investigate the local risk-minimization approach for a combined financial-insurance model where there are restrictions on the information available to the insurance company. In particular we assume that, at any time, the insurance company may observe the number of deaths from a specific portfolio of insured individuals but not the mortality hazard rate. We consider a financial market driven by a general semimartingale and we aim to hedge unit-linked life insurance contracts via the local risk-minimization approach under partial information. The Föllmer-Schweizer decomposition of the insurance claim and explicit formulas for the optimal strategy for pure endowment and term insurance contracts are provided in terms of the projection of the survival process on the information flow. Moreover, in a Markovian framework, this leads to a filtering problem with point process observations.

DIERKES, THOMAS; ORTMANN, KARL MICHAEL. *On the efficient utilisation of duration.* 29–37. In this article we present a new approach to estimate the change of the present value of a given cashflow pattern caused by an interest rate shift. Our approximation is based on analysing the evolution of the present value function through a linear differential equation. The outcome is far more accurate than the standard approach achieved by a Taylor expansion. Furthermore, we derive an approximation formula of second order that produces nearly accurate results. In particular, we prove that our method is superior to any known alternative approximation formula based on duration. In order to demonstrate the power of this improved approximation we apply it to coupon bonds, level annuities, and level perpetuities. We finally generalise the approach to a non-flat term structure. As for applications in insurance, we estimate the change of the discounted value of future liabilities due to a proportional shift in the set of capital accumulation factors. These findings are of particular importance to capital adequacy calculations with respect to interest rate stress scenarios that are part of regulatory solvency requirements.

FARD, FARZAD ALAVI. *Analytical pricing of vulnerable options under a generalized jump-diffusion model.* 19–28. In this paper we propose a model to price European vulnerable options. We formulate their credit risk in a reduced form model and the dynamics of the spot price in a completely random generalized jump-diffusion model, which nests a number of important

models in finance. We obtain a closed-form price for the vulnerable option by (1) determining an equivalent martingale measure, using the Esscher transform and (2) manipulating the pay-off structure of the option four further times, by using the Esscher–Girsanov transform.

FELLINGHAM, GILBERT W; KOTTAS, ATHANASIOS; HARTMAN, BRIAN M. *Bayesian nonparametric predictive modeling of group health claims*. 1–10. Models commonly employed to fit current claims data and predict future claims are often parametric and relatively inflexible. An incorrect model assumption can cause model misspecification which leads to reduced profits at best and dangerous, unanticipated risk exposure at worst. Even mixture models may not be sufficiently flexible to properly fit the data. Using a Bayesian nonparametric model instead can dramatically improve claim predictions and consequently risk management decisions in group health practices. The improvement is significant in both simulated and real data from a major health insurer's medium-sized groups. The nonparametric method outperforms a similar Bayesian parametric model, especially when predicting future claims for new business (entire groups not in the previous year's data). In our analysis, the nonparametric model outperforms the parametric model in predicting costs of both renewal and new business. This is particularly important as healthcare costs rise around the world.

LANDRIAULT, DAVID; LI, BIN; LI, SHU. *Analysis of a drawdown-based regime-switching Lévy insurance model*. 98–107. In this paper, we propose a new drawdown-based regime-switching (DBRS) Lévy insurance model in which the underlying drawdown process is used to model an insurer's level of financial distress over time, and to trigger regime-switching transitions. By some analytical arguments, we derive explicit formulas for a generalized two-sided exit problem. We specifically state conditions under which the survival probability is not trivially zero (which corresponds to the positive security loading conditions of the proposed model). The regime-dependent occupation time until ruin is later studied. As a special case of the general DBRS model, a regime-switching premium model is given further consideration. Connections with other existing risk models (such as the loss-carry-forward tax model of Albrecher and Hipp, 2007) [Albrecher, H, Hipp, C, (2007), Lundberg's risk process with tax, *Blätter der Deutsche Gesellschaft für Versicherungsmathematik* (2008) 28(1):13-28] are established.

LANDRIAULT, DAVID; SHI, TIANXIANG. *Occupation times in the MAP risk model*. 75–82. Occupation times have so far been primarily analyzed in the class of Lévy processes, most notably some of its special cases, by capitalizing on the stationary and independence property of the process increments. In this paper, we relax this assumption and provide a closed-form expression for the Laplace transform of occupation times for surplus processes governed by a Markovian claim arrival process [MAP: Markovian arrival process]. This will naturally allow us to revisit some occupation time results for the compound Poisson risk model. We also identify the density of the total duration of negative surplus and its individual contributions when the number of claims occurring with negative surplus levels is jointly studied. Finally, a numerical example in an Erlang-2 renewal risk process is also considered.

LI, SHI; LANDRIAULT, DAVID; LEMIEUX, CHRISTIANE. *A risk model with varying premiums: its risk management implications*. 38–46. In this paper, we consider a risk model which allows the insurer to partially reflect the recent claim experience in the determination of the next period's premium rate. In a ruin context, similar mechanisms to the one proposed in this paper have been studied by, e.g., Tsai and Parker (2004) [Tsai, C., Parker, G., 2004. Ruin probabilities: classical versus credibility. NTU International Conference on Finance, 2004], Afonso *et al.* (2009)

[L B Afonso, A D Reis, H R Waters, Calculating continuous time ruin probabilities for a large portfolio with varying premiums, *ASTIN Bulletin* 39 (2009): 117-136] and Loisel and Trufin (2013) [S Loisel, J Trufin, Ultimate ruin probability in discrete time with Bühlmann credibility premium adjustments, *Bulletin Français d'Actuariat*, 13 (2013): 73-102]. In our proposed risk model, we assume that the effective premium rate is determined based on the surplus increments between successive random review times. When review times are distributed as a combination of exponentials and claim arrivals follow a compound Poisson process, we derive a matrix-form defective renewal equation for the Gerber-Shiu function, and provide an explicit expression for the discounted joint density of the surplus prior to ruin and the deficit at ruin. Numerical examples are later considered to numerically evaluate certain ruin-related quantities. A comparison with their counterparts in a constant premium rate model is also presented.

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ASSA, HIRBOD. *On optimal reinsurance policy with distortion risk measures and premiums.* 70–75. In this paper, we consider the problem of optimal reinsurance design, when the risk is measured by a distortion risk measure and the premium is given by a distortion risk premium. First, we show how the optimal reinsurance design for the ceding company, the reinsurance company and the social planner can be formulated in the same way. Second, by introducing the “marginal indemnification functions”, we characterize the optimal reinsurance contracts. We show that, for an optimal policy, the associated marginal indemnification function only takes the values zero and one. We will see how the roles of the market preferences and premiums and that of the total risk are separated.

BADILA, E S; BOXMA, ONNO J; RESING, J A C. *Two parallel insurance lines with simultaneous arrivals and risks correlated with inter-arrival times.* 48–61. We investigate an insurance risk model that consists of two reserves which receive income at fixed rates. Claims are being requested at random epochs from each reserve and the interclaim times are generally distributed. The two reserves are coupled in the sense that at a claim arrival epoch, claims are being requested from both reserves and the amounts requested are correlated. In addition, the claim amounts are correlated with the time elapsed since the previous claim arrival. We focus on the probability that this bivariate reserve process survives indefinitely. The infinite-horizon survival problem is shown to be related to the problem of determining the equilibrium distribution of a random walk with vector-valued increments with ‘reflecting’ boundary. This reflected random walk is actually the waiting time process in a queueing system dual to the bivariate ruin process. Under assumptions on the arrival process and the claim amounts, and using Wiener-Hopf factorization with one parameter, we explicitly determine the Laplace-Stieltjes transform of the survival function, c.q., the two-dimensional equilibrium waiting time distribution. Finally, the bivariate transforms are evaluated for some examples, including for proportional reinsurance, and the bivariate ruin functions are numerically calculated using an efficient inversion scheme.

BAKAR, S ABU; HAMZAH, N A; MAGHSOUDI, M; NADARAJAH, SARALEES. *Modeling loss data using composite models.* 146–154. We develop several new composite models based on the Weibull distribution for heavy tailed insurance loss data. The composite model assumes different weighted distributions for the head and tail of the distribution and several such models have been

introduced in the literature for modelling insurance loss data. For each model proposed in this paper, we specify two parameters as a function of the remaining parameters. These models are fitted to two real insurance loss data sets and their goodness-of-fit is tested. We also present an application to risk measurements and compare the suitability of the models to empirical results.

BARMALZAN, GHOBAD; NAJAFABADI, AMIR T PAYANDEH; BALAKRISHNAN, NARAYANASWAMY. *Stochastic comparison of aggregate claim amounts between two heterogeneous portfolios and its applications*. 235–241. The aggregate claim amount in a particular time period is a quantity of fundamental importance for proper management of an insurance company and also for pricing of insurance coverages. In this paper, we show that the proportional hazard rates (PHR) model, which includes some well-known distributions such as exponential, Weibull and Pareto distributions, can be used as the aggregate claim amount distribution. We also present some conditions for the use of exponentiated Weibull distribution as the claim amount distribution. The results established here complete and extend the well-known result of Khaledi and Ahmadi (2008) [B Khaledi, S S Ahmadi, 2008. On stochastic comparison between aggregate claim amounts, *Journal of Statistical Planning and Inference* (2008) 138: 3121–3129].

BERNARDI, ENRICO; FALANGI, FEDERICO; ROMAGNOLI, SILVIA. *A hierarchical copula-based world-wide valuation of sovereign risk*. 155–169. We propose a new model for the aggregation of risks that is very flexible and useful in high dimensional problems. We propose a copula-based model that is both hierarchical and hybrid (HYC for short), because: (i) the dependence structure is modelled as a hierarchical copula, (ii) it unifies the idea of the clusterized homogeneous copula-based approach (CHC for short) and its limiting version (LHC for short) proposed in Bernardi and Romagnoli (2012, 2013) [E Bernardi, S Romagnoli, Limiting Loss distribution on a Hierarchical copula-based model, *International Review of Applied Financial Issues and Economics* (2012) 4(2): 126–135; E Bernardi, S Romagnoli, A clusterized copula-based probability distribution of a counting variable for high-dimensional problems, *Journal of Credit Risk* (2013) 88(11): 2591–2607]. Based on this, we compute the loss function of a world-wide sovereign debt portfolio which accounts for a systemic dependence of all countries, in line with a global valuation of financial risks. Our approach enables us to take into account the non-exchangeable behaviour of a sovereign debts' portfolio clustered into several classes with homogeneous risk and to recover a possible risks' hierarchy. A comparison between the HYC loss surface and those computed through a pure limiting approach, which is commonly used in high dimensional problems, is presented and the impact of the concentration and the granularity errors is appreciated. Finally the impact of an enlargement of the dependence structure is discussed, in the context of a geographical area sub-portfolios analysis now relevant to determine the risk contributions of subgroups under the presence of a wider dependence structure. This argument is presented in relation to the evaluation of the insurance premium and the collateral related to the designed project of an euro-insurance-bond.

BIGNOZZI, VALERIA; PUCCETTI, GIOVANNI; RÜSCHENDORF, LUDGER. *Reducing model risk via positive and negative dependence assumptions*. 17–26. We give analytical bounds on the Value-at-Risk and on convex risk measures for a portfolio of random variables with fixed marginal distributions under an additional positive dependence structure. We show that assuming positive dependence information in our model leads to reduced dependence uncertainty spreads compared to the case where only marginals information is known. In more detail, we show that in our model the assumption of a positive dependence structure improves the best-possible lower estimate of a risk measure, while leaving unchanged its worst-possible upper risk bounds. In a

similar way, we derive for convex risk measures that the assumption of a negative dependence structure leads to improved upper bounds for the risk while it does not help to increase the lower risk bounds in an essential way. As a result we find that additional assumptions on the dependence structure may result in essentially improved risk bounds.

BOUDREAU, MATHIEU; COSSETTE, HÉLÈNE; MARCEAU, ÉTIENNE. Erratum to: ‘Risk models with dependence between claim occurrences and severities for Atlantic hurricanes’ [Insurance Mathematics Economics (2014) 54: 123–132] 298. Erratum to: “Risk models with dependence between claim occurrences and severities for Atlantic hurricanes” [Insurance Mathematics Economics (2014) 54: 123–132] - <http://dx.doi.org/10.1016/j.insmatheco.2013.11.002>.

CHAU, K W; YAM, S C P; YANG, H. *Fourier-cosine method for Gerber-Shiu functions*. 170–180. In this article, we provide a systematic study on effectively approximating the Gerber-Shiu functions, which is a hardly touched topic in the current literature, by incorporating the recently popular Fourier-cosine method. Fourier-cosine method has been a prevailing numerical method in option pricing theory since the work of Fang and Oosterlee (2009) [F Fang, C Oosterlee, A novel pricing method for European options based on Fourier-cosine series expansions, *SIAM Journal of Scientific Computing* (2009) 31: 826–848]. Our approximant of Gerber-Shiu functions under Lévy subordinator model has $O(n)$ computational complexity in comparison with that of $O(n \log n)$ via the fast Fourier transform algorithm. Also, for Gerber-Shiu functions within our proposed refined Sobolev space, we introduce an explicit error bound, which seems to be absent from the literature. In contrast with our previous work (Chau *et al.*, 2015) [K W Chau, S C P Yam, H. Yang, Fourier-cosine method for ruin probabilities, *Journal of Computational and Applied Mathematics* (2015) 281: 94–106], this error bound is more conservative without making heavy assumptions on the Fourier transform of the Gerber-Shiu function. The effectiveness of our result will be further demonstrated in the numerical studies.

CHEN, XU; YANG, XIANG-QUN. *Optimal consumption and investment problem with random horizon in a BMAP model*. 197–205. In this paper, we consider the consumption and investment problem with random horizon in a Batch Markov Arrival Process (BMAP) model. The investor invests her wealth in a financial market consisting of a risk-free asset and a risky asset. The price processes of the riskless asset and the risky asset are modulated by a continuous-time Markov chain, which is the phase process of a BMAP. The possible consumption or investment are restricted to a sequence of random discrete time points which are determined by the same BMAP. The investor has only consumption opportunities at some of these random time points, has both consumption and investment opportunities at some other random time points, and can do nothing at the remaining random time points. The object of the investor is to select the consumption–investment strategy that maximizes the expected total discounted utility. The purpose of this paper is to analyze the impact of the consumption–investment opportunity and the economic state on the value functions and consumption–investment strategies. The general solution and the exact solution under the assumption that the consumption and the terminal wealth are evaluated by the power utility are obtained. Finally, a numerical example is presented.

CHUNXIANG, A; LI, ZHONGFEI. *Optimal investment and excess-of-loss reinsurance problem with delay for an insurer under Heston’s SV model*. 181–196. This paper considers an optimal investment and excess-of-loss reinsurance problem with delay for an insurer under Heston’s stochastic volatility (SV) model. Suppose that the insurer is allowed to purchase excess-of-loss

reinsurance and invests her surplus in a financial market consisting of one risk-free asset and one risky asset whose price process is described by Heston's SV model. Under the consideration of the performance-related capital inflow/outflow, the wealth process of the insurer is modelled by a stochastic differential delay equation. The insurer's aim is to maximize the expected exponential utility of the combination of terminal wealth and average performance wealth. By adopting the dynamic programming approach, the optimal strategies and the optimal value functions are derived explicitly under two cases: the investment-reinsurance case and the investment-only case. Finally, some numerical examples and sensitivity analysis are provided for our results.

DI BERNARDINO, ELENA; FERNÁNDEZ-PONCE, J M; PALACIOS-RODRÍGUEZ, F; RODRÍGUEZ-GRÍÑOLO, M R. *On multivariate extensions of the conditional Value-at-Risk measure*. 1–16. CoVaR is a systemic risk measure proposed by Adrian and Brunnermeier (2011) able to measure a financial institution's contribution to systemic risk and its contribution to the risk of other financial institutions. CoVaR stands for conditional Value-at-Risk, i.e. it indicates the Value at Risk for a financial institution that is conditional on a certain scenario. In this paper, two alternative extensions of the classic univariate Conditional Value-at-Risk are introduced in a multivariate setting. The two proposed multivariate CoVaRs are constructed from level sets of multivariate distribution functions (resp. of multivariate survival distribution functions). These vector-valued measures have the same dimension as the underlying risk portfolio. Several characterizations of these new risk measures are provided in terms of the copula structure and stochastic orderings of the marginal distributions. Interestingly, these results are consistent with existing properties on univariate risk measures. Furthermore, comparisons between existent risk measures and the proposed multivariate CoVaR are developed. Illustrations are given in the class of Archimedean copulas. Estimation procedure for the multivariate proposed CoVaRs is illustrated in simulated studies and insurance real data.

GAO, JIN; ULM, ERIC R. *Optimal allocation and consumption with guaranteed minimum death benefits, external income and term life insurance*. 87–98. Because human capital is often the largest asset an investor possesses when he is young, protecting human capital from potential risks should be considered as a part of overall investment advice. The risk of the loss of the policyholder's human capital—the mortality risk—to the household can be partially hedged by a term life insurance policy. Guaranteed Minimum Death Benefits (GMDB) in Variable Annuities (VA) can also help policyholders hedge the risk of the loss of human capital. Therefore, GMDB options and term life insurance can be considered as substitute goods. However, they are not perfect substitute as GMDB and term life have their own properties: Term life insurance has no correlation with equity markets, and it is purely regarded as a protection for human capital; the variable annuity products follow the performance of equity markets, and the GMDB is a protection against downside risks on equity markets as well as human capital. We find that fairly priced GMDB options fail to add value to a VA contract if a term life policy is available.

GHOSSOUB, MARIO. *Vigilant measures of risk and the demand for contingent claims*. 27–35. We examine a class of utility maximization problems with a non-necessarily law-invariant utility, and with a non-necessarily law-invariant risk measure constraint. Under a consistency requirement on the risk measure that we call Vigilance, we show the existence of optimal contingent claims, and we show that such optimal contingent claims exhibit a desired monotonicity property. Vigilance is satisfied by a large class of risk measures, including all distortion risk measures and some classes of robust risk measures. As an illustration, we consider a problem of optimal insurance design where the premium principle satisfies the vigilance property, hence covering a large collection of

commonly used premium principles, including premium principles that are not law-invariant. We show the existence of optimal indemnity schedules, and we show that optimal indemnity schedules are nondecreasing functions of the insurable loss.

GUAN, GUOHUI; LIANG, ZONGXIA. *Mean-variance efficiency of DC pension plan under stochastic interest rate and mean-reverting returns*. 99–109. This paper studies the optimization problem of DC pension plan under mean-variance criterion. The financial market consists of cash, bond and stock. Similar to Guan and Liang (2014) [G H Guan, Z X Liang, Optimal reinsurance and investment strategies for insurer under interest rate and inflation risks, Insurance Mathematics and Economics (2014) 55: 105–115], we assume that the instantaneous interest rate is an affine process including the Cox-Ingersoll-Ross (CIR) model and Vasicek model. However, we assume that the expected return of the stock follows a completely different mean-reverting process, which can well display the bear and bull features of the market, and the market price of the stock index is the Ornstein-Uhlenbeck process. The pension manager thus has to undertake the risks of interest rate and market price of stock index. Besides, a special stochastic contribution rate is formulated. The goal of the pension manager is to maximize the expected terminal value and minimize the variance of terminal value. We will use the technique developed by Guan and Liang (2014) to tackle this problem and derive the closed-forms of efficient frontier and strategies. Numerical analysis is given in the end of this paper to show the economic behaviour of the efficient frontier and strategies.

HAINAUT, DONATIEN. *Evaluation and default time for companies with uncertain cash flows*. 276–285. In this study, we propose a modelling framework for evaluating companies financed by random liabilities, such as insurance companies or commercial banks. In this approach, earnings and costs are driven by double exponential jump-diffusion processes and bankruptcy is declared when the income falls below a default threshold, which is proportional to the charges. A change of numeraire, under the Esscher risk neutral measure, is used to reduce the dimension. A closed form expression for the value of equity is obtained in terms of the expected present value operators, with and without disinvestment delay. In both cases, we determine the default threshold that maximizes the shareholder's equity. Subsequently, the probabilities of default are obtained by inverting the Laplace transform of the bankruptcy time. In numerical applications of the proposed model, we apply a procedure for calibration based on market and accounting data to explain the behaviour of shares for two real-world examples of insurance companies.

HE, LIN; LIANG, ZONGXIA. *Optimal assets allocation and benefit outgo policies of DC pension plan with compulsory conversion claims*. 227–234. In this paper, we study optimal asset allocation and benefit outgo policies of DC (defined contribution) pension plan. We extend He and Liang model (2013a,b) [Lin He, Zongxia Liang, Optimal dynamic asset allocation strategy for ELA scheme of DC pension plan during the distribution phase, Insurance Mathematics and Economics (2013a) 52: 404–410; Lin He, Zongxia Liang, Optimal investment strategy for the DC plan with the return of premium clauses in a mean-variance framework, Insurance Mathematics and Economics (2013b) 53: 643–649] to describe dynamics of individual fund scale during distribution period. The fund scale is affected by investment return, benefit outgo and mortality credit. The management of the pension plan controls the asset allocation and benefit outgo policies to achieve the objective of pension members. The goal of the management is to minimize accumulated deviations between the actual benefit outgo and a pre-set target during the whole distribution period. The performance function (criterion) is the weighted average of the square and linear deviations to express more penalty on negative deviation than positive deviation. Using HJB

(Hamilton-Jacobi-Bellman) equations and variational inequality methods, the closed-forms of the optimal policies are derived. The counterintuitive effect of the optimal proportion allocated in the risky asset with respect to the fund scale is also derived, and the optimal benefit outgo has the form of the spread method. Moreover, we use Monte Carlo Methods (MCM) to analyze economic behaviours of the optimal asset allocation and benefit outgo policies.

HUA, LEI. *Tail negative dependence and its applications for aggregate loss modeling*. 135–145. Tail order of copulas can be used to describe the strength of dependence in the tails of a joint distribution. When the value of tail order is larger than the dimension, it may lead to tail negative dependence. First, we prove results on conditions that lead to tail negative dependence for Archimedean copulas. Using the conditions, we construct new parametric copula families that possess upper tail negative dependence. Among them, a copula based on a scale mixture with a generalized gamma random variable (GGS copula) is useful for modelling asymmetric tail negative dependence. We propose mixed copula regression based on the GGS copula for aggregate loss modelling of a medical expenditure panel survey dataset. For this dataset, we find that there exists upper tail negative dependence between loss frequency and loss severity, and the introduction of tail negative dependence structures significantly improves the aggregate loss modelling.

JEVTCIC, PETAR; REGIS, LUCA. *Assessing the solvency of insurance portfolios via a continuous-time cohort model*. 36–47. This paper evaluates the solvency of a portfolio of assets and liabilities of an insurer subject to both longevity and financial risks. Liabilities are evaluated at fair-value and, as a consequence, interest-rate risk can affect both the assets and the liabilities. Longevity risk is described via a continuous-time cohort model. We evaluate the effects of natural hedging strategies on the risk profile of an insurance portfolio in run-off. Numerical simulations, calibrated to UK historical data, show that systematic longevity risk is of particular importance and needs to be hedged. Natural hedging can improve the solvency of the insurer, if interest-rate risk is appropriately managed. We stress that asset allocation choices should not be independent of the composition of the liability portfolio of the insurer.

LI, HAO; O'HARE, COLIN; ZHANG, XIBIN. *A semiparametric panel approach to mortality modeling*. 264–270. During the past twenty years, there has been a rapid growth in life expectancy and an increased attention on funding for old age. Attempts to forecast improving life expectancy have been boosted by the development of stochastic mortality modelling, for example the Cairns-Blake-Dowd (CBD) 2006 model [A J G Cairns, D Blake, K Dowd, A two-factor model for stochastic mortality with parameter uncertainty: theory and calibration, *Journal of Risk and Insurance* (2006) 73: 687–718]. The most common optimization method for these models is maximum likelihood estimation (MLE) which relies on the assumption that the number of deaths follows a Poisson distribution. However, several recent studies have found that the true underlying distribution of death data is overdispersed in nature (see Cairns *et al.* 2009 [A J G Cairns *et al.*, A quantitative comparison of stochastic mortality models using data from England & Wales and the United States, *North American Actuarial Journal* (2009) 13(1): 1-35] and Dowd *et al.* 2010 [K. Dowd *et al.*, Evaluating the goodness of fit of stochastic mortality models, *Insurance Mathematics and Economics* (2010) 47: 255–265]). Semiparametric models have been applied to many areas in economics but there are very few applications of such models in mortality modelling. In this paper we propose a local linear panel fitting methodology to the CBD model which would free the Poisson assumption on number of deaths. The parameters in the CBD model will be considered as smooth functions of time instead of being treated as a bivariate random walk with drift process in the current literature. Using the mortality data of several developed countries,

we find that the proposed estimation methods provide comparable fitting results with the MLE method but without the need of additional assumptions on number of deaths. Further, the 5-year-ahead forecasting results show that our method significantly improves the accuracy of the forecast.

LI, JACKIE; HABERMAN, STEVEN; HAINAUT, DONATIEN. *On the effectiveness of natural hedging for insurance companies and pension plans*. 286–297. Natural hedging is one possible method to reduce longevity risk exposure for an annuity provider or a pension plan. In this paper, we provide an assessment of the effectiveness of natural hedging between annuity and life products, using the correlated Poisson Lee-Carter model, Poisson common factor model, product-ratio model, and historical simulation. Our analysis is based on the mortality experience of UK assured lives, pensioners, and annuitants, and the national population of England and Wales. We consider a range of different scenarios, and find that the level of risk reduction is significant in general, with an average of around 60%. These results have important implications for those insurers, reinsurers, and pension plan sponsors who are seeking ways to hedge their unwanted risk exposures.

LIN, TZULING; WANG, CHOU-WEN; TSAI, CARY CHI-LIANG. *Age-specific copula-AR-GARCH mortality models*. 110–124. In this paper, we propose AR-GARCH (autoregression-generalized autoregressive conditional heteroskedasticity) models to fit and forecast mortality rates for a given age by two alternative approaches. Specifically, one approach is to fit a time series of mortality rates for some age to an AR(n)-GARCH(1, 1) model, and project the mortality rate for that age in the next n th year; the other is to fit an AR(1)-GARCH(1, 1) model, and project the mortality rates recursively for the age in the next consecutive years. Further, we employ the copula method to capture the inter-age mortality dependence. Adopting mortality data of Japan, the UK, and the USA, we demonstrate that it is indispensable to consider the conditional heteroskedasticity in our mortality models which provide better performances in out-of-sample projection and prediction intervals with a higher degree of coverage than the Lee-Carter model. Finally, we numerically illustrate with mortality data of Japan that VaR (Value at Risk) values for longevity risk, regarded as additional reserves for annuity or pension providers, will be overestimated if the conditional heteroskedasticity or/and the inter-age mortality dependence structure are ignored.

MAMMEN, ENNO; MARTÍNEZ MIRANDA, MARÍA DOLORES; NIELSEN, JENS PERCH. *In-sample forecasting applied to reserving and mesothelioma mortality*. 76–86. This paper shows that recent published mortality projections with unobserved exposure can be understood as structured density estimation. The structured density is only observed on a sub-sample corresponding to historical calendar times. The mortality forecast is obtained by extrapolating the structured density to future calendar times using that the components of the density are identified within sample. The new method is illustrated on the important practical problem of forecasting mesothelioma for the UK population. Full asymptotic theory is provided. The theory is given in such generality that it also introduces mathematical statistical theory for the recent continuous chain ladder model. This allows a modern approach to classical reserving techniques used every day in any non-life insurance company around the globe. Applications to mortality data and non-life insurance data are provided along with relevant small sample simulation studies.

SCHMIDLI, HANSPETER. *Extended Gerber-Shiu functions in a risk model with interest*. 271–275. We consider a compound Poisson risk model with interest. The Gerber-Shiu discounted penalty function is modified with an additional penalty for reaching a level above the initial capital. We show that the problem can be split into two independent problems; an original Gerber-Shiu function and a first passage problem. We also consider the case of negative interest. Finally,

we apply the results to a model considered by Embrechts and Schmidli (1994) [P Embrechts, H Schmidli, Ruin estimation for a general insurance risk model, *Advanced Applied Probability* (1994) 26: 404–422].

SORDO, MIGUEL A; SUÁREZ-LLORENS, ALFONSO; BELLO, ALFONSO J. *Comparison of conditional distributions in portfolios of dependent risks*. 62–69. Given a portfolio of risks, we study the marginal behaviour of the i th risk under an adverse event, such as an unusually large loss in the portfolio or, in the case of a portfolio with a positive dependence structure, to an unusually large loss for another risk. By considering some particular conditional risk distributions, we formalize, in several ways, the intuition that the i th component of the portfolio is riskier when it is part of a positive dependent random vector than when it is considered alone. We also study, given two random vectors with a fixed dependence structure, the circumstances under which the existence of some stochastic orderings among their marginals implies an ordering among the corresponding conditional risk distributions.

TAN, CHONG IT; LI, JACKIE; LI, JOHNNY SIU-HANG; BALASOORIYA, UDITHA. *Optimal relativities and transition rules of a bonus-malus system*. 255–263. When a bonus-malus system with a single set of optimal relativities and a set of simple transition rules is implemented, two inadequacy scenarios are induced because all policyholders are subject to the same a posteriori premium relativities (level transitions) independent of their a priori characteristics (current levels occupied). In this paper we propose a new objective function in the determination of optimal relativities that directly incorporates the a priori expected claim frequencies to partially address one of the inadequacy scenarios. We derive the analytical solution for the optimal relativities under a financial equilibrium constraint. Furthermore, we introduce a metric called effectiveness of transition rules to compare the different specifications of transition rules. We also argue that varying transition rules which are more flexible in addressing the other inadequacy scenario may be more effective than their corresponding simple rules.

TARGINO, RODRIGO S; PETERS, GARETH W; SHEVCHENKO, PAVEL V. *Sequential Monte Carlo Samplers for capital allocation under copula-dependent risk models*. 206–226. In this paper we assume a multivariate risk model has been developed for a portfolio and its capital derived as a homogeneous risk measure. The Euler (or gradient) principle, then, states that the capital to be allocated to each component of the portfolio has to be calculated as an expectation conditional to a rare event, which can be challenging to evaluate in practice. We exploit the copula-dependence within the portfolio risks to design a Sequential Monte Carlo Samplers based estimate to the marginal conditional expectations involved in the problem, showing its efficiency through a series of computational examples.

ZHOU, JIANG; WU, LAN. *The time of deducting fees for variable annuities under the state-dependent fee structure*. 125–134. We investigate the total time of deducting fees for variable annuities with state-dependent fee. This fee charging method is studied recently by Bernard *et al.* (2014) [C Bernard, M Hardy, A Mackay, State-dependent fees for variable annuity guarantees, *Astin Bulletin* (2014) 44: 559–585] and Delong (2014) [L Delong, Pricing and hedging of variable annuities with state-dependent fees, *Insurance Mathematics and Economics* (2014) 58: 24–33] in which the fees deducted from the policyholder's account depend on the account value. However, both of them have not considered the problem of analyzing probabilistic properties of the total time of deducting fees. We approximate the maturity of a general variable annuity contract by combinations of exponential distributions which are (weakly) dense in the space that is composed

of all probability distributions on the positive axis. Working under general jump diffusion process, we derive analytic formulas for the expectation of the time of deducting fees as well as its Laplace transform.

ZHU, HUIMING; DENG, CHAO; YUE, SHENGJIE; DENG, YINGCHUN. *Optimal reinsurance and investment problem for an insurer with counterparty risk*. 242–254. This paper analyzes the optimal proportional reinsurance and investment problem for an insurer in a defaultable market. We assume that the reinsurance premium is calculated via the exponential premium principle. The insurer can allocate his/her wealth among the following securities: a bank account, a risky stock asset and a corporate bond. We decompose the original optimization problem into two sub-problems: a pre-default case and a post-default case. The optimal reinsurance and investment policies that maximize the expected CARA [utility of the terminal wealth are explicitly derived. Numerical examples are given to illustrate our results, and we discuss relevant economic insights obtained from these results.

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BAUMGARTNER, CAROLIN; GRUBER, LUTZ F; CZADO, CLAUDIA. *Bayesian total loss estimation using shared random effects*. 194–201. The pricing of insurance policies requires estimates of the total loss. The traditional compound model imposes an independence assumption on the number of claims and their individual sizes. Bivariate models, which model both variables jointly, eliminate this assumption. A regression approach allows policy holder characteristics and product features to be included in the model. This article presents a bivariate model that uses joint random effects across both response variables to induce dependence effects. Bayesian posterior estimation is done using Markov Chain Monte Carlo (MCMC) methods. A real data example demonstrates that our proposed model exhibits better fitting and forecasting capabilities than existing models.

CHEN, YIQING; LIU, JIAJUN; LIU, FEI. *Ruin with insurance and financial risks following the least risky FGM dependence structure*. 98–106. Recently, Chen (2011) [Y Chen, The finite-time ruin probability with dependent insurance and financial risks, *Journal of Applied Probability* 48(4) (2011), pp. 1035–1048] studied the finite-time ruin probability in a discrete-time risk model in which the insurance and financial risks form a sequence of independent and identically distributed random pairs with common bivariate Farlie-Gumbel-Morgenstern (FGM) distribution. The parameter of the FGM distribution governs the strength of dependence, with a smaller value of corresponding to a less risky situation. For the subexponential case with $-1 < \theta \leq 1$, a general asymptotic formula for the finite-time ruin probability was derived. However, the derivation there is not valid for the least risky case $\theta = -1$. In this paper, we complete the study by extending it to $\theta = -1$. The new formulas for $\theta = -1$ look very different from, but are intrinsically consistent with, the existing one for $-1 < \theta \leq 1$, and they offer a quantitative understanding on how significantly the asymptotic ruin probability decreases when switches from its normal range to its negative extremum.

DANESI, IVAN LUCIANO; HABERMAN, STEVEN; MILLOSSOVICH, PIETRO. *Forecasting mortality in subpopulations using Lee-Carter type models: a comparison*. 151–161. The relative performance of multipopulation stochastic mortality models is investigated. When targeting mortality rates, we consider five extensions of the well known Lee-Carter single population

extrapolative approach. As an alternative, we consider similar structures when mortality improvement rates are targeted. We use a dataset of deaths and exposures of Italian regions for the years 1974–2008 to conduct a comparison of the models, running a battery of tests to assess the relative goodness of fit and forecasting capability of different approaches. Results show that the preferable models are those striking a balance between complexity and flexibility.

DENUIT, MICHEL; KIRILIOUK, ANNA; SEGERS, JOHAN. *Max-factor individual risk models with application to credit portfolios*. 162–172. Individual risk models need to capture possible correlations as failing to do so typically results in an underestimation of extreme quantiles of the aggregate loss. Such dependence modelling is particularly important for managing credit risk, for instance, where joint defaults are a major cause of concern. Often, the dependence between the individual loss occurrence indicators is driven by a small number of unobservable factors. Conditional loss probabilities are then expressed as monotone functions of linear combinations of these hidden factors. However, combining the factors in a linear way allows for some compensation between them. Such diversification effects are not always desirable and this is why the present work proposes a new model replacing linear combinations with maxima. These max-factor models give more insight into which of the factors is dominant.

FAN, LIDA; SIU, TAK KUEN; WANG, RONGMING. *Pricing annuity guarantees under a double regime-switching model*. 62–78. This paper is concerned with the valuation of equity-linked annuities with mortality risk under a double regime-switching model, which provides a way to endogenously determine the regime-switching risk. The model parameters and the reference investment fund price level are modulated by a continuous-time, finite-time, observable Markov chain. In particular, the risk-free interest rate, the appreciation rate, the volatility and the martingale describing the jump component of the reference investment fund are related to the modulating Markov chain. Two approaches, namely, the regime-switching Esscher transform and the minimal martingale measure, are used to select pricing kernels for the fair valuation. Analytical pricing formulas for the embedded options underlying these products are derived using the inverse Fourier transform. The fast Fourier transform approach is then used to numerically evaluate the embedded options. Numerical examples are provided to illustrate our approach.

FINNER, H; KERN, P; SCHEER, M. *On some compound distributions with Borel summands*. 234–244. The generalized Poisson distribution is well known to be a compound Poisson distribution with Borel summands. As a generalization we present closed formulas for compound Bartlett and Delaporte distributions with Borel summands and a recursive structure for certain compound shifted Delaporte mixtures with Borel summands. Our models are introduced in an actuarial context as claim number distributions and are derived only with probabilistic arguments and elementary combinatorial identities. In the actuarial context related compound distributions are of importance as models for the total size of insurance claims for which we present simple recursion formulas of Panjer type.

GAN, GUOJUN; LIN, SHELDON. *Valuation of large variable annuity portfolios under nested simulation: a functional data approach*. 138–150. A variable annuity (VA) is equity-linked annuity product that has rapidly grown in popularity around the world in recent years. Research up to date on VA largely focuses on the valuation of guarantees embedded in a single VA contract. However, methods developed for individual VA contracts based on option pricing theory cannot be extended to large VA portfolios. Insurance companies currently use nested simulation to value guarantees for VA portfolios but efficient valuation under nested simulation for a large VA

portfolio has been a real challenge. The computation in nested simulation is highly intensive and often prohibitive. In this paper, we propose a novel approach that combines a clustering technique with a functional data analysis technique to address the issue. We create a highly non-homogeneous synthetic VA portfolio of 100,000 contracts and use it to estimate the dollar Delta of the portfolio at each time step of outer loop scenarios under the nested simulation framework over a period of 25 years. Our test results show that the proposed approach performs well in terms of accuracy and efficiency.

GOMES-GONÇALVES, ERIKA; GZYL, HENRYK; MAYORAL, SILVIA. *Two maxentropic approaches to determine the probability density of compound risk losses*. 42–53. Here we present an application of two maxentropic procedures to determine the probability density distribution of a compound random variable describing aggregate risk, using only a finite number of empirically determined fractional moments. The two methods that we use are the Standard method of Maximum Entropy (SME) and the method of Maximum Entropy in the Mean (MEM). We analyze the performance and robustness of these two procedures in several numerical examples, in which the frequency of losses is Poisson and the individual losses are lognormal random variables. We shall verify that the reconstructions obtained pass a variety of statistical quality criteria, and provide good estimations of VaR and TVaR, which are important measures for risk management purposes. As side product of the work, we obtain a rather accurate numerical description of the density of such compound random variable.

These approaches are also used to develop a procedure to determine the distribution of the individual losses from the knowledge of the total loss. Thus, if the only information available is the total loss, and the nature of the frequency of losses is known, the method of maximum entropy provides an efficient method to determine the individual losses as well.

GOVORUN, MARIA; LATOUCHE, GUY; LOISEL, STÉPHANE. *Phase-type aging modeling for health dependent costs*. 173–183. In the present paper we develop recursive algorithms to evaluate the distribution of the net present value (abbreviated as “NPV”) of a health care contract. The duration of the program is a random variable representing the lifetime of an individual. We suggest a discrete time phase-type approach to model individual health care costs. In this approach, annual health care costs depend naturally on the health state of the individual. We also derive the distribution of the NPV assuming that annual health care costs are iid random variables. We demonstrate analytically that, under special parametrization, the model with iid costs gives a similar expectation of the NPV to the one of the model with health dependent costs. We propose techniques to evaluate the impact of health related events and demonstrate it on numerical examples. Based on Canadian government data on health expenditures, we study the impact on the NPV of the health cost structure by age.

HUANG, YI-CHIEH; TZENG, LARRY Y; ZHAO, LIN. *Comparative ambiguity aversion and downside ambiguity aversion*. 257–269. This paper first defines an increase in ambiguity and an increase in downside ambiguity. We then provide comparative criteria for ambiguity aversion and downside ambiguity aversion. Different from the finding that the comparative criterion for risk aversion is variant with the measure of the premium to reduce risks, we show that the criteria remain the same, whether the premiums to reduce ambiguity and downside ambiguity are measured by utility or money. Under the criteria, a more ambiguity-averse (downside-ambiguity-averse) individual is shown to spend more effort in reducing ambiguity (downside ambiguity) than a less ambiguity-averse (downside-ambiguity-averse) individual.

JENSEN, N R; STEFFENSEN, M. *Personal finance and life insurance under separation of risk aversion and elasticity of substitution*. 28–41. In a classical Black-Scholes market, we establish a connection between two seemingly different approaches to continuous-time utility optimization. We study the optimal consumption, investment, and life insurance decision of an investor with power utility and an uncertain lifetime. To separate risk aversion from elasticity of inter-temporal substitution, we introduce certainty equivalents. We propose a time-inconsistent global optimization problem, and we present a verification theorem for an equilibrium control. In the special case without mortality risk, we discover that our optimization approach is equivalent to recursive utility optimization with Epstein-Zin preferences in the sense that the two approaches lead to the same result. We find this interesting since our optimization problem has an intuitive interpretation as a global maximization of certainty equivalents and since recursive utility, in contrast to our approach, gives rise to severe differentiability problems. Also, our optimization approach can there be seen as a generalization of recursive utility optimization with Epstein-Zin preferences to include mortality risk and life insurance.

LUO, XIAOLIN; SHEVCHENKO, PAVEL V. *Valuation of variable annuities with guaranteed minimum withdrawal and death benefits via stochastic control optimization*. 5–15. In this paper we present a numerical valuation of variable annuities with combined Guaranteed Minimum Withdrawal Benefit (GMWB) and Guaranteed Minimum Death Benefit (GMDB) under optimal policyholder behaviour solved as an optimal stochastic control problem. This product simultaneously deals with financial risk, mortality risk and human behaviour. We assume that market is complete in financial risk and mortality risk is completely diversified by selling enough policies and thus the annuity price can be expressed as appropriate expectation. The computing engine employed to solve the optimal stochastic control problem is based on a robust and efficient Gauss-Hermite quadrature method with cubic spline. We present results for three different types of death benefit and show that, under the optimal policyholder behaviour, adding the premium for the death benefit on top of the GMWB can be problematic for contracts with long maturities if the continuous fee structure is kept, which is ordinarily assumed for a GMWB contract. In fact for some long maturities it can be shown that the fee cannot be charged as any proportion of the account value — there is no solution to match the initial premium with the fair annuity price. On the other hand, the extra fee due to adding the death benefit can be charged upfront or in periodic installment of fixed amount, and it is cheaper than buying a separate life insurance.

MALINOVSKII, VSEVOLOD K. *Business planning for a profit-seeking insurer under deficiency of information*. 215–226. This paper aims to model a profit-seeking firm in a regulated competitive insurance market in an epoch when future annual market prices become poorly predictable. It occurs when more and more non-antagonistic contenders cut their prices seeking for individual success. It aggravates randomness pertaining to insurance casualties. This paper deals with multi-year control strategy of a profit-seeking insurer aiming in this epoch to comply each year with legal solvency requirements, to keep its portfolio size more or less stable, and to keep business attractive for investments.

MALINOVSKII, VSEVOLOD K. *On rational pricing for a profit-seeking insurer in the year of hard market*. 107–117. The aim of this paper is to examine rational pricing of a profit-seeking insurer carrying on its business when underwriting cycle is in its upper phase. We focus on migration of insureds wishing to get the same services at a lower price. We investigate pricing which maximizes the insurer's intrinsic value linked to its attractiveness for investors, provided that its solvency position is fixed. The main tool in this paper is explicit bounds on ruin capital in Lundberg risk

model with migration. Written in terms of elementary functions, they make the solution straightforward.

MENG, HUI; LI, SHUANMING; ZHOU, JIN. *A reinsurance game between two insurance companies with nonlinear risk processes*. 91–97. In this paper, we consider a stochastic differential reinsurance game between two insurance companies with nonlinear (quadratic) risk control processes. We assume that the goal of each insurance company is to maximize the exponential utility of the difference between its terminal surplus and that of its competitor at a fixed terminal time T . First, we give an explicit partition (including nine subsets) of time interval $[0, T]$. Further, on every subset, an explicit Nash equilibrium strategy is derived by solving a pair of Hamilton-Jacobi-Bellman equations. Finally, for some special cases, we analyze the impact of time t and quadratic control parameter on the Nash equilibrium strategy and obtain some simple partition of $[0, T]$. Based on these results, we apply some numerical analysis of the time t , quadratic control parameter and competition sensitivity parameter on the Nash equilibrium strategy and the value function.

PICHLER, ALOIS; SHAPIRO, ALEXANDER. *Minimal representation of insurance prices*. 184–193. This paper prices insurance contracts by employing law invariant, coherent risk measures from mathematical finance. We demonstrate that the corresponding premium principle enjoys a minimal representation. Uniqueness – in a sense specified in the paper – of this premium principle is derived from this initial result. The representations are derived from a result by Kusuoka, which is usually given for nonatomic probability spaces. We extend this setting to premium principles for spaces with atoms, as this is of particular importance for insurance. Further, stochastic order relations are employed to identify the minimal representation. It is shown that the premium principles in the minimal representation are extremal with respect to the order relations. The tools are finally employed to explicitly provide the minimal representation for premium principles, which are important in actuarial practice.

PUN, CHI SENG; WONG, HOI YING. *Robust investment-reinsurance optimization with multiscale stochastic volatility*. 245–256. This paper investigates the investment and reinsurance problem in the presence of stochastic volatility for an ambiguity-averse insurer (AAI) with a general concave utility function. The AAI concerns about model uncertainty and seeks for an optimal robust decision. We consider a Brownian motion with drift for the surplus of the AAI who invests in a risky asset following a multiscale stochastic volatility (SV) model. We formulate the robust optimal investment and reinsurance problem for a general class of utility functions under a general SV model. Applying perturbation techniques to the Hamilton-Jacobi-Bellman-Isaacs (HJBI) equation associated with our problem, we derive an investment-reinsurance strategy that well approximates the optimal strategy of the robust optimization problem under a multiscale SV model. We also provide a practical strategy that requires no tracking of volatility factors. Numerical study is conducted to demonstrate the practical use of theoretical results and to draw economic interpretations from the robust decision rules.

SHEN, YANG; ZENG, YAN. *Optimal investment–reinsurance strategy for mean–variance insurers with square-root factor process*. 118–137. This paper studies an optimal investment-reinsurance problem for an insurer with a surplus process represented by the Cramé-Lundberg model. The insurer is assumed to be a mean–variance optimizer. The financial market consists of one risk-free asset and one risky asset. The market price of risk depends on a Markovian, affine-form, square-root stochastic factor process, while the volatility and appreciation rate of the risky asset are given by non-Markovian, unbounded processes. The insurer faces the decision-making problem of

choosing to purchase reinsurance, acquire new business and invest its surplus in the financial market such that the mean and variance of its terminal wealth is maximized and minimized simultaneously. We adopt a backward stochastic differential equation approach to solve the problem. Closed-form expressions for the efficient frontier and efficient strategy of the mean–variance problem are derived. Numerical examples are presented to illustrate our results in two special cases, the constant elasticity of variance model and Heston’s model.

WILLMOT, GORDON E. *On a partial integrodifferential equation of Seal’s type.* 54–61. In this paper we generalize a partial integrodifferential equation satisfied by the finite time ruin probability in the classical Poisson risk model. The generalization also includes the bivariate distribution function of the time of and the deficit at ruin. We solve the partial integrodifferential equation by Laplace transforms with the help of Lagrange’s implicit function theorem. The assumption of mixed Erlang claim sizes is then shown to result in tractable computational formulas for the finite time ruin probability as well as the bivariate distribution function of the time of and the deficit at ruin. A more general partial integrodifferential equation is then briefly considered.

WU, HUILING; ZHANG, LING; CHEN, HUA. *Nash equilibrium strategies for a defined contribution pension management.* 202–214. This paper studies the time-consistent investment strategy for a defined contribution (DC) pension plan under the mean-variance criterion. Since the time horizon of a pension fund management problem is relatively long, two background risks are taken into account: the inflation risk and the salary risk. Meanwhile, there are a risk-free asset, a stock and an inflation-indexed bond available in the financial market. The extended Hamilton-Jacobi-Bellman (HJB for short) equation of the equilibrium value function and the verification theorem corresponding to our problem are presented. The closed-form time-consistent investment strategy and the equilibrium efficient frontier are obtained by stochastic control technique. The effects of the inflation and stochastic income on the equilibrium strategy and the equilibrium efficient frontier are illustrated by mathematical and numerical analysis. Finally, we compare in detail the time-consistent results in our paper with the pre-commitment one and find the distinct properties of these two results.

YANG, BOWEN; LI, JACKIE; BALASOORIYA, UDITHA. *Using bootstrapping to incorporate model error for risk-neutral pricing of longevity risk.* 16–27. Where mortality projection is concerned, it is essential to quantify the extent of the prediction error. This is especially important in light of the aggravating risk of longevity and as a result the increasing demand for longevity-linked products. In the literature so far, only parameter error and process error have been considered jointly while the issue of model error has yet been systematically studied. In this paper, we propose a method to account for process error, parameter error and model error in an integrated manner by modifying the semi-parametric bootstrapping technique. We apply the method to two data sets from the Continuous Mortality Investigation (CMI) and use the simulated scenarios to price the q -forward contracts via the maximum entropy approach. We find that model selection has a significant impact on the risk-neutral valuation results and thus it is crucial to incorporate model error in mortality projection.

YAO, KAI; QIN, ZHONGFENG. *A modified insurance risk process with uncertainty.* 227–233. An insurance risk process is traditionally considered by describing the claim process via a renewal reward process and assuming the total premium to be proportional to the time with a constant ratio. It is usually modelled as a stochastic process such as the compound Poisson process, and historical data are collected and employed to estimate the corresponding parameters of probability distributions.

However, there exists the case of lack of data such as for a new insurance product. An alternative way is to estimate the parameters based on experts' subjective belief and information. Therefore, it is necessary to employ the uncertain process to model the insurance risk process. In this paper, we propose a modified insurance risk process in which both the claim process and the premium process are assumed to be renewal reward processes with uncertain factors. Then we give the inverse uncertainty distribution of the modified process at each time. On this basis, we derive the ruin index which has an explicit expression based on given uncertainty distributions.

ZHOU, JIANG; WU, LAN. *Valuing equity-linked death benefits with a threshold expense strategy*. 79–90. We investigate equity-linked investment products with a threshold expense strategy, under which an insurance company will collect expenses continuously from the policyholder's account only when the account value is lower than a pre-specified level. The logarithmic value of the policyholder's account, before deducting any fees, is described by a jump diffusion process which is independent of the time-to-death random variable. The distribution of the time-to-death random variable is approximated by a combination of exponential distributions, which are dense in the space of density functions on $[0, \infty)$. We characterize the Laplace transform of the distribution of a general refracted jump diffusion process through some integro-differential equations. Besides, the distribution of a refracted double exponential jump diffusion process at an independent exponential random variable is derived, from which closed-form formulas to evaluate the total expenses and the fair fee rates are obtained. Finally, we illustrate our results by some numerical examples.

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DONNELLY, CATHERINE; ENGLUND, MARTIN; NIELSEN, JENS PERCH; TANGGAARD, CARSTEN. *Asymmetric information, self-selection, and pricing of insurance contracts: the simple no-claims case*. 757–780. This article presents an optional bonus-malus contract based on a priori risk classification of the underlying insurance contract. By inducing self-selection, the purchase of the bonus-malus contract can be used as a screening device. This gives an even better pricing performance than both an experience rating scheme and a classical no-claims bonus system. An application to the Danish automobile insurance market is considered.

ECKLES, DAVID L; HALEK, MARTIN; ZHANG, RONGRONG. *Information risk and the cost of capital*. 861–882. This article applies a unique accruals measure to empirically test whether accruals quality affects the cost of capital for property-liability insurers. We utilize insurer loss reserve errors to accurately measure the quality of accruals. This measure, as well as conventional accruals measures, is used to investigate the extent to which accruals quality is priced into both debt and equity capital. We find that accruals quality is priced into debt capital; however, we find virtually no evidence that accruals quality is priced into equity capital. Our results should be of

particular interest to insurers as it affects pricing ability. Specifically, insurers who provide primary debtholders (i.e., policyholders) less information risk are able to command higher prices. Furthermore, our results suggest that insurance is not a diversifiable asset.

FINKELSTEIN, AMY; POTERBA, JAMES. *Testing for asymmetric information using “unused observables” in insurance markets: evidence from the U.K. annuity market.* 709–734. This article tests for asymmetric information in the U.K. annuity market of the 1990s by trying to identify “unused observables,” attributes of individual insurance buyers that are correlated both with subsequent claims experience and with insurance demand but that insurance companies did not use to set insurance prices. Unlike the widely used positive correlation test for asymmetric information, which searches for a positive correlation between insurance demand and risk experience, the unused observables test is not confounded by heterogeneity in individual preference parameters that may affect insurance demand. We identify residential location as an unused observable in the U.K. annuity market of this period. Even though residential location was observed by all market participants, the decision not to condition prices on it created the same types of market inefficiencies that arise when annuity buyers have private information about mortality risk. Our findings raise questions about how insurance companies select the set of buyer attributes that they use in setting policy prices. In the decade following the period that we study, U.K. insurance companies changed their pricing practices and began to condition annuity prices on a buyer’s postcode.

GATZERT, NADINE; KELLNER, RALF. *The effectiveness of gap insurance with respect to basis risk in a shareholder value maximization setting.* 831–860. The purchase of index-linked alternative risk transfer instruments can lead to basis risk, if the insurer’s loss is not fully dependent on the index. One way to reduce basis risk is to additionally purchase gap insurance, which fills the gap between an insurer’s actual loss and the index-linked instrument’s payout. The previous literature detects gains in the effectiveness of this hedging strategy in a mean–variance framework. The aim of this article is to extend this analysis and to examine the effectiveness of gap insurance in a shareholder value maximization framework under solvency constraints. Our results show that purchasing gap insurance can generally increase the hedging effectiveness in multiple ways by reducing basis risk, thus increasing shareholder value and, at the same time, lowering shortfall risk.

HILPERT, CHRISTIAN; LI, JING; SZIMAYER, ALEXANDER. *The effect of secondary markets on equity-linked life insurance with surrender guarantees.* 943–968. Many equity-linked life insurance products offer the possibility to surrender policies prematurely. Secondary markets for policies with surrender guarantees influence both policyholders and insurers. We show that secondary markets lead to a gap in policy value between insurer and policyholder. Insurers increase premiums to adjust for higher surrender rates of customers and optimized surrender behaviour by investors acquiring the policies on secondary markets. Hence, the existence of secondary markets is not necessarily profitable for the primary policyholders. The result depends on the demand for and the supply of the contracts brought to the secondary markets.

HUANG, RACHEL J; TZENG, LARRY Y; WANG, KILI C. *Heterogeneity of the accident externality from driving.* 735–756. This article examines the accident externality from driving in terms of loss probability and severity by using a unique individual-level data set with more than 3 million observations from Taiwan. Two types of accident externality are, respectively, measured: the average number of kilometers driven per month per vehicle and the total number of speeding tickets per month. For both variables, we find significant evidence to support the existence of the

accident externality. Moreover, we find that the accident externality is heterogeneous in terms of the vehicles' characteristics.

MALINOVSKII, VSEVOLOD K. *Reflexivity in competition-originated underwriting cycles*. 883–906. This article addresses the fundamental observation that aggressive newcomers seeking greater market share trigger the industry response of reducing rates that may gradually fall below marginal cost. In this study, the concept of reflexivity as connection between the participants' thinking and the situation in which they participate is applied. This article suggests applying as an insurance regulation technique, while the competition-originated cycle is in its early stage, the triplets of year-end market share, profit, and solvency indicators. It emphasizes the need for applying all these characteristics together, rather than the first two.

SPIERDIJK, LAURA; KONING, RUUD H. *Estimating outstanding claim liabilities: the role of unobserved risk factors*. 803–830. This article proposes a new method for estimating claim liabilities. Our approach is based on the observation from contract theory that there is information asymmetry between the insurer and the policyholder about the risks incurred by the latter. We show that unobserved heterogeneity allows for a form of experience learning that can reduce this asymmetry, which makes it easier for the insurer to distinguish between high-risk and low-risk claimants. We evaluate our approach in the context of disability insurance for self-employed and show that it results in more accurate best estimates of outstanding claim liabilities.

SPINDLER, MARTIN; WINTER, JOACHIM; HAGMAYER, STEFFEN. *Asymmetric information in the market for automobile insurance: evidence from Germany*. 781–801. Asymmetric information is an important phenomenon in insurance markets, but the empirical evidence on the extent of adverse selection and moral hazard is mixed. Because of its implications for pricing, contract design, and regulation, it is crucial to test for asymmetric information in specific insurance markets. In this article, we analyze a recent data set on automobile insurance in Germany, the largest such market in Europe. We present and compare a variety of statistical testing procedures. We find that the extent of asymmetric information depends on coverage levels and on the specific risks covered, which enhances the previous literature. Within the framework of Chiappori *et al.* (2006), we also test whether drivers have realistic expectations concerning their loss distribution, and we analyze the market structure.

VIAUROUX, CHRISTELLE. *Tax sharing in insurance markets: a useful parameterization*. 907–942. We use a principal–agent framework to evaluate the economic impacts of imposing a tax on insurance payment in presence of moral hazard using a Gamma conditional distribution of losses. Our results show that any tax paid by the insured would lower his effort to prevent loss, hence increasing insurance payments and decreasing profits. This result is reinforced as the insured becomes more risk averse unless the distribution of losses is uniform. We find that any decrease in the insurer's tax share would generate an overall decrease in welfare unless the insured characteristics prevent him from reacting to the policy.

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COLE, CASSANDRA R; FIER, STEPHEN G; CARSON, JAMES M; ANDREWS, DEMETRA. *The impact of insurer name changes on the demand for insurance*. 173–204. Corporate name

changes are relatively common events, with some evidence suggesting that name changes are strategic in nature. Although prior research has examined the effect of name changes on the firm, these studies have focused primarily on the stock price reaction to name changes. Such a focus has a number of limitations, including a reliance on samples that consist solely of publicly traded firms and an inability to determine whether the source of the impact is driven by increases in revenue, increases in efficiency, and/or reductions in costs. We overcome these limitations by testing the impact of corporate name changes on U.S. property-casualty insurers using detailed statutory data. We find a significant and positive relation between name changes and subsequent growth in premiums. The results are robust across various model specifications and suggest that name changes contain information that consumers interpret as meaningfully positive.

FEI, WENAN; FLUET, CLAUDE; SCHLESINGER, HARRIS. *Uncertain bequest needs and long-term insurance contracts*. 125–148. We examine how long-term life insurance contracts can be designed to incorporate uncertain future bequest needs. An individual who buys a life insurance contract early in life is often uncertain about the future financial needs of his or her family, in the event of an untimely death. Ideally, the individual would like to insure the risk of having high future bequest needs, but since bequest motives are typically unverifiable, a contract directly insuring these needs is not feasible. We derive a long-term life insurance contract that is incentive compatible and achieves a higher welfare level than the naïve strategy of delaying the purchase of insurance until after one's bequest needs are known. We also examine the welfare effects of our contract and we show how third-party financial products, although beneficial to the individual in the short run, can be detrimental to one's ex ante utility.

FONG, JOELLE H; PIGGOTT, JOHN; SHERRIS, MICHAEL. *Longevity selection and liabilities in public sector pension funds*. 33–64. This article assesses the cost and risk faced by public sector, defined benefit plan providers arising from uncertain mortality, including longevity selection, mortality improvements, and unexpected systematic shocks. Using longitudinal microdata on Australian pensioners, we quantify the extent of longevity selection at both aggregate and scheme level. We also show that as the age-membership structure in a pension scheme matures, scheme-specific longevity selection risk and systematic shocks become quantitatively more important and have larger consequences for plan liabilities than aggregate selection risk or the impact of mortality improvements.

LI, BINGQING; LIAO, PU; XU, JINGFENG. *An OLG model for optimal investment and insurance decisions*. 149–172. This article uses overlapping generation (OLG) model to study individuals' optimal decision on consumption, investment, insurance, and education expenses. To the best of our knowledge, we are the first to discuss the individuals' demand for insurance with the consideration of intergenerational transfer payments. In the article, we incorporate insurance into the OLG model to describe individuals' optimization problem on consuming and saving, and we solve the optimal proportions of expenditure on investment, survival insurance, life insurance, and education, with the optimal consumption to be the remaining parts of expenditure. We observe that the numerical outputs are consistent with the actual data. It is also interesting to find that the human capital investment is independent of both risky asset investment and individuals' risk aversion coefficient.

MORA, NADA. *Lender exposure and effort in the syndicated loan market*. 205–252. This article tests for asymmetric information problems between the lead arranger and the participants in a lending syndicate. One problem comes from adverse selection, whereby the lead has a private informational advantage over participants. A second problem comes from moral hazard, whereby the lead puts less effort in monitoring when it retains a smaller loan share. Applying an instrumental variables

strategy using lending limits, borrower performance is improved by increasing the lead's share. The focus is on separating moral hazard from adverse selection and the results are consistently indicative of monitoring. First, the lead's share is more important for revocable credit lines than for fully funded term facilities. Second, a lead with greater liquidity risk reduces its share resulting in worse borrower performance, but its liquidity risk does not affect the quality of credits it chooses to syndicate in the first place. Third, covenants are paired with a higher lead share, and the sensitivity between share and borrower ex post performance is greater on loans with more covenants.

ROTHSCHILD, CASEY. *Nonexclusivity, linear pricing, and annuity market screening*. 1–32. I develop a graphical approach for studying two-type adverse-selection insurance markets with (1) compulsory contracting, (2) linear pricing, (3) nonexclusive contracting, and (4) multiple indemnity states. The UK compulsory annuity market is a natural application. Despite fully linear pricing and nonexclusivity, screening of different types into distinct contracts—using the pattern of insurance payments across distinct indemnity states rather than quantity restrictions—is possible. Efficient screening involves distorting both types' contracts away from first best contracts, for example, via front-loaded annuities. These distortions are attributable to convexification constraints that I identify as the nonexclusive, linear-pricing analog of canonical incentive compatibility constraints.

ZHANG, LI; NIELSON, NORMA. *Solvency analysis and prediction in property–casualty insurance: incorporating economic and market predictors*. 97–124. This article extends the insolvency prediction literature by incorporating macroeconomic conditions and state-specific factors. The models achieve greater generalizability and predictive accuracy than earlier research while giving fewer false positives. At the firm level, we find insurers with less diversified business, sufficient cash flow, high return on equity, lower leverage, fewer failed Insurance Regulatory Information System ratio tests, and membership in a larger group are less likely to become insolvent. Our findings support the argument that insolvency likelihood increases for insurers domiciled in states with stricter solvency supervision and/or states with less favorable insurance market conditions, and during soft markets; insolvency risk is negatively related to the slope of the yield curve. Our findings also imply that insurers respond efficiently to changes in such market factors as market return, inflation, and catastrophic losses.

ZHOU, RUI; SIU-HANG LI, JOHNNY; TAN, KEN SENG. *Economic pricing of mortality-linked securities: a tâtonnement approach*. 65–96. In previous research on pricing mortality-linked securities, the no-arbitrage approach is often used. However, this approach, which takes market prices as given, is difficult to implement in today's embryonic market where there are few traded securities. In this article, we tackle the pricing problem from a different angle by considering methods that are more related to fundamental economic concepts. Specifically, we treat the pricing work as a Walrasian tâtonnement process, in which prices are determined through a gradual calibration of supply and demand. We illustrate the proposed pricing framework with a hypothetical mortality-linked security and mortality data from the U.S. population.

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AMAYA, DIEGO; GAUTHIER, GENEVIÈVE; LÉAUTIER, THOMAS-OLIVIER. *Dynamic risk management: investment, capital structure, and hedging in the presence of financial frictions*. 359–399.

This article develops a dynamic risk management model to determine a firm's optimal risk management strategy. This strategy has two elements. First, for low-leverage values, the firm fully hedges its operating cash flow exposure, due to the convexity of its cost of capital. When leverage exceeds a very high threshold, the firm gambles for resurrection and stops hedging. Second, the firm manages its capital structure through dividend distributions and investment. When leverage is low, the firm replaces depreciated assets, fully invests in opportunities if they arise, and distribute dividends, all of these together to achieve its optimal capital structure. As leverage increases, the firm stops paying dividends, while fully investing. After a certain leverage, the firm also reduces investment until it stops investing completely. The model predictions are consistent with empirical observations.

BRUNEAU, CATHERINE; SGHAIER, NADIA. *Cyclicality in the French property-liability insurance industry: new findings over the recent period*. 433–462. This article reinvestigates the presence and the causes of the underwriting cycle in the French property-liability insurance industry as displayed by the combined ratio for the 1963–2008 period. The question is still a timely issue if we refer to regulation issues and the recent proposals in the Solvency framework to take into account the fluctuations of the profitability in specifying the solvency capital requirement. In the literature, two approaches are traditionally adopted to investigate the underwriting cycle. The first one refers to an endogenous characterization of the cyclical properties from an AR(2) model. The second one claims that the cycle in the property-liability insurance has exogenous sources related to the financial markets and the general economy. In this article, we reconcile the two approaches by using a smooth transition regression model. This model shows that the AR(2) model is relevant in a first regime where the capacity constraint is binding. In contrast, the fluctuations in the combined ratio are positively influenced by the lagged stock market return in a second regime where the capacity is not constrained, as for the most recent period. Moreover, we find that the current capacity is related to the lagged inflation rate in the latter case. These results confirm the idea that the European rules regarding the solvency capital requirement for insurance companies should take into account the state of the economy and the financial markets.

FILIPOVIC, DAMIR; KREMSLEHNER, ROBERT; MUERMANN, ALEXANDER. *Optimal investment and premium policies under risk shifting and solvency regulation*. 261–288. Limited liability creates an incentive for insurers to increase the risk of the assets and liabilities at the expense of policyholders. We show that solvency capital requirements restrict the set of feasible investment and premium policies and can thereby improve efficiency under the risk-shifting problem. This finding becomes particularly important in light of Solvency II, the forthcoming European risk-based solvency regime for insurers. We provide evidence for Solvency II-related efficiency effects in a calibration study for a nonlife insurer average portfolio.

GRACE, MARTIN F; LEVERTY, J TYLER; PHILLIPS, RICHARD D; SHIMPI, PRAKASH. *The value of investing in enterprise risk management*. 289–316. Prior studies show that enterprise risk management improves firm performance. This article investigates which aspects of enterprise risk management add value. We find that the use of economic capital models and dedicated risk managers improve operating performance. Requiring the dedicated risk manager report to the board of directors or to the chief executive officer (CEO) also increases value. The following combination of enterprise risk management initiatives yields the greatest increase in firm value: a simple economic capital model, a dedicated risk manager that is a cross-functional committee, and requiring the risk manager report to the board or CEO.

HUBER, CARIN; GATZERT, NADINE; SCHMEISER, HATO. *How does price presentation influence consumer choice? The case of life insurance products.* 401–432. Life insurance is an important product for many individuals, both to protect dependents against the premature death of an income producer and to provide savings in later retirement years. These kinds of products, however, can be quite complex. Regulatory authorities and consumers currently ask for more cost transparency with respect to product components (e.g., risk premium for death benefits, savings premium, cost of investment guarantee) and administration costs. The aim of this article is to measure the effects of different forms of presenting the price of life insurance contract components and especially of embedded investment guarantees on consumer evaluation of those products. The intention is to understand the extent to which price presentation affects consumer demand. This is done by means of an experimental study and by focusing on unit-linked life insurance products. Our findings reveal that contrary to other consumer products, there are no precise effects of “price bundling” and “price optic” on consumer evaluation and purchase intention in the case of life insurance. Consumer experience and price perception, however, yield a significant moderating effect.

MILLO, GIOVANNI; CARMECI, GAETANO. *A subregional panel data analysis of life insurance consumption in Italy.* 317–340. We propose a subregional panel approach to the determinants of life insurance development, with new methodological tools, applied to Italian data. Our sample has enough variability in observables and less unobserved heterogeneity than cross-country ones, but is potentially affected by spatial dependence and serial correlation. We propose an encompassing estimator, showing that the spatial diffusion process of life insurance is driven by idiosyncratic shocks in neighbors. Our results partly reconcile the aggregate perspective with survey evidence supporting, in contrast to international studies, a negative link between education and risk aversion, and identifying the positive effect of young dependents predicted by theory.

PAI, JEFFREY; BOYD, MILTON; PORTH, LYSA. *Insurance premium calculation using credibility analysis: an example from livestock mortality insurance.* 341–357. A major problem facing livestock producers is animal mortality risk. Livestock mortality insurance is still at the initial stages, and premium computation approaches are still relatively new and will require more research. This study seeks to provide a first step for developing a better understanding of livestock insurance as a solution to mortality risk, as it explores improved methods for livestock mortality insurance modelling procedures, and premium computation, using credibility analysis. The purpose of this study is to develop improved estimates for livestock mortality insurance premiums for Canada under a credibility framework. We illustrate our approach through one example using livestock data from 1999 to 2007.

YIN, NA. *Partial benefits in the social security disability insurance program.* 463–504. The current U.S. Social Security Disability Insurance program is an all-or-nothing system that has been criticized for creating strong work disincentives. In an empirically grounded and calibrated life-cycle model, I simulate behavioural responses to a partial disability benefit system, a policy alternative to the current program, which allows individuals to claim partial disability and combine earnings with disability benefits. Simulation results show financial savings for the program as well as welfare improvements for individuals with disabilities.

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FONG, JOELLE H; SHAO, ADAM W; SHERRIS, MICHAEL. *Multistate actuarial models of functional disability*. 41–59. Long-term-care (LTC) costs are expected to significantly increase over the coming decades as the Baby Boom generation nears retirement. Recent policy discussions in the United State have focused on expanding the private LTC insurance market so as to alleviate some of the pressure on public programs. An important and fundamental input to the pricing of LTC insurance products is a set of age- and sex-specific functional status transition rates that can flexibly take into account alternative benefit trigger specifications. We apply generalized linear models to evaluate disability transitions for individuals in old age based on a large sample of U.S. elderly. We estimate a multistate model for LTC insurance applications and find significant differences in disability rate patterns and levels between our set of estimates and those separately estimated using an earlier approach developed by the Society of Actuaries. Our results suggest that the elderly face a 10% chance of becoming LTC disabled only at ages past 90, rather than in their 80 s. Furthermore, age patterns of recovery are found to differ significantly between the sexes. We also show that these estimates of transition probability are sensitive to the definition of “LTC disability,” which has implications for the design of benefit triggers for private and public LTC insurance programs.

FRECH III, H E; SMITH, MICHAEL P. *Anatomy of a slow-motion health insurance death spiral*. 60–72. Adverse selection death spirals in health insurance are dramatic and, so far, exotic economic events. The possibility of death spirals has garnered recent policy and popular attention because the pricing regulations in the Affordable Care Act (ACA) of 2010 make health plans more vulnerable to them (though some other aspects of the ACA limit them). Most death spirals tracked in the literature have involved selection against a group health plan that was dropped quickly by the employer. In this article, we empirically document a death spiral in individual health insurance that was apparently triggered by a block closure in 1981 and developed slowly because the insurer partially subsidized the block. We show that premiums rose dramatically from around the time of the block closure to at least 2009 (the last year of available data). By 2009, some, but very few, policyholders remained in the block, and premiums were roughly seven times that of a yardstick we developed. The history of this slow-moving event is directly relevant to current policy discussions because of both adverse selection in general and the particular problems induced by closing a block.

TSAI, CARY CHI-LIANG; YANG, SHUAI. *A linear regression approach to modeling mortality rates of different forms*. 1–23. In this article, we propose a linear regression approach to modelling mortality rates of different forms. First, we repeat to fit a mortality sequence for each of K years (called the fitting years) with another mortality sequence of equal length for some year (called the base year) differing by t_j years ($j = 1, \dots, K$) using a simple linear regression. Then we fit the sequences of the estimated slope and intercept parameters of length K , respectively, with the sequence of $\{t_j\}$ by each of the simple linear regression and random walk with drift models. The sequences of the fitted slope and intercept parameters can be used for forecasting deterministic and stochastic mortality rates. Forecasting performances are compared among these two approaches and the Lee-Carter model. The CBD model is also included for comparisons for an elderly age group. Moreover, we give a central-death-rate-linked security to hedge mortality/longevity risks. Optimal units, purchased from the special purpose vehicle, which maximize the hedge effectiveness

for life insurers and annuity providers, respectively, are derived and can be expressed in terms of the cumulative distribution function of the standard normal random variable. A measure with hedge cost involved, called hedge effectiveness rate, for comparing risk reduction amount per dollar spent among mortality models is proposed. Finally, numerical examples are presented for illustrations.

WANG, RUODU; PENG, LIANG; YANG, JINGPING. *CreditRisk + model with dependent risk factors*. 24–40. The CreditRisk + model is widely used in industry for computing the loss of a credit portfolio. The standard CreditRisk + model assumes independence among a set of common risk factors, a simplified assumption that leads to computational ease. In this article, we propose to model the common risk factors by a class of multivariate extreme copulas as a generalization of bivariate Fréchet copulas. Further we present a conditional compound Poisson model to approximate the credit portfolio and provide a cost-efficient recursive algorithm to calculate the loss distribution. The new model is more flexible than the standard model, with computational advantages compared to other dependence models of risk factors.

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ARNOLD-GAILLE, SÉVERINE; SHERRIS, MICHAEL. *Causes-of-death mortality: what do we know on their dependence?* 116–128. Over the last century, the assumption usually made was that causes of death are independent, although it is well-known that dependancies exist. Recent developments in econometrics allow, through Vector Error Correction Models (VECMs), to model multivariate dynamic systems including time dependency between economic variables. Common trends that exist between the variables may then be highlighted, the relation between these variables being represented by a long-run equilibrium relationship. In this work, VECMs are developed for causes-of-death mortality. We analyze the five main causes of death across 10 major countries representing a diversity of developed economies. The World Health Organization website provides cause-of-death information for about the last 60 years. Our analysis reveals that long-run equilibrium relationships exist between the five main causes of death, improving our understanding of the nature of dependence between these competing risks over recent years. It also highlights that countries usually had different past experience in regard to cause-of-death mortality trends, and, thus, applying results from one country to another may be misleading.

HWANG, YA-WEN; CHANG, SHIH-CHIEH; WU, YANG-CHE. *Capital forbearance, ex ante life insurance guaranty schemes, and interest rate uncertainty*. 94–115. Insurance guaranty funds have been adopted in many countries to compensate policyholders for losses resulting from insurers' insolvencies. In this article we focus on the risk-based premiums in ex ante insurance guaranty schemes since a preassessment mechanism could reduce the shareholders' incentive to engage in risk-taking behaviour. We derive the closed-form solutions of the risk-based premium charged by the insurance guaranty fund in a setting that incorporates financial leverage, asset allocation, early closure, and capital forbearance during the grace period. Most importantly, we assume that the interest rate is stochastic, and we find that the premium is underpriced if the uncertainty of the interest rate is neglected by the insurance guaranty fund. Moreover, the influence of stochastic interest rate for the premium is more significant when we consider the capital forbearance mechanism. The impacts of the key factors in our model that decide the fair premium of the guaranty fund are examined

numerically. The results of our analysis could provide valuable insights for regulators in terms of revising regulatory policies and insurance guaranty schemes.

MUNROE, DAVID; ODELL, DAVID; SANDLER, SERGE; ZEHNWIRTH, BEN. *A solution for Solvency II quantitative requirements modeling with long-tail liabilities*. 79–93. The European Parliament's Solvency II Directive introduced a new regulation for insurance and reinsurance business designed to establish a consistently improved level of policyholder protection by means of a three-pillar process. Pillar 1 of the directive contains quantitative requirements for the insurance industry in respect to technical provisions (TPs) and the solvency capital requirement (SCR). The cornerstone of Solvency II one-year risk horizon is the Fair Value of Liabilities (FVL). The SCR and Economic Balance Sheet at inception should be able to withstand a first future calendar year in distress (at the level of 1-in-200-year event). We provide a rigorous statistical treatment of the risk metrics required to fulfil Solvency II requirements for internal models applicable to reserve risk with long-tail liabilities. The proposed internal model is novel in not relying on the proportionality proxy. A tractable simulation based solution ensures adequate capital to restore the economic balance sheet to its FVL should the first future calendar year be in distress.

RUSSO, VINCENZO; GIACOMETTI, ROSELLA; RACHEV, SVETLOZAR; FABOZZI, FRANK J. *A three-factor model for mortality modeling*. 129–141. In this article, we propose a three-factor model for mortality modelling in which the dynamic of the entire term structure of mortality rates can be expressed in closed form as a function of three variables x , t , and y . Due to this feature, we are able to project mortality rates across age (x), across time (t), and for y years ($y \geq 1$) after t . Our proposal differs from most existing models where only the one-year mortality rate is considered ($y = 1$). The model is characterized by three parameters that are calibrated yearly. We describe the stochastic dynamic of the three factors with correlated autoregressive processes. We generate stochastic scenarios accounting for the historical mortality trend in a consistent manner with the Gompertz law. Using population mortality data for Italy, the U.S., and the U.K., the model's forecasting capability is assessed, and a comparative analysis with other models is provided.

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ARO, HELENA; DJEHICHE, BOUALEM; LÖFDAHL, BJÖRN. *Stochastic modelling of disability insurance in a multi-period framework*. 88–106. We propose a stochastic semi-Markovian framework for disability modelling in a multi-period discrete-time setting. The logistic transforms of disability inception and recovery probabilities are modelled by means of stochastic risk factors and basis functions, using counting processes and generalized linear models. The model for disability inception also takes IBNR claims into consideration. We fit various versions of the models into Swedish disability claims data.

BERGEL, AGNIESZKA I; EGÍDIO DOS REIS, ALFREDO D. *Further developments in the Erlang(n) risk process*. 32–48. For actuarial applications, we consider the Sparre-Andersen risk model when the interclaim times are Erlang(n) distributed. We first address the problem of solving an integro-differential equation that is satisfied by the survival probability and other probabilities, and show an alternative and improved method to solve such equations to that presented by Li (2008) [Li, S. (2008). A note on the maximum severity of ruin in an Erlang(n) risk process. Bulletin of the Swiss Association of Actuaries, 167-180]. This is done by considering the roots with positive real parts of the generalized Lundberg's equation, and establishing a one-one relation between them and the solutions of the integro-differential equation mentioned before. Afterwards, we apply our findings above in the computation of the distribution of the maximum severity of ruin. This computation depends on the non-ruin probability and on the roots of the fundamental Lundberg's equation. We illustrate and give explicit formulae for Erlang(3) interclaim arrivals with exponentially distributed single claim amounts and Erlang(2) interclaim times with Erlang(2) claim amounts. Finally, considering an interest force, we consider the problem of calculating the expected discounted dividends prior to ruin, finding an integro-differential equation that they satisfy and solving it. Numerical examples are also provided for illustration.

KOCOVIC, JELENA; COJBAŠIĆ, VESNA; JOVANOVIĆ, MILAN. *Estimating a tail of the mixture of log-normal and inverse Gaussian distribution*. 49–58. In this paper, we estimate a tail of the mixture of log-normal and inverse Gaussian distribution in order to model extreme historical losses. Good estimate of the tail is essential in reinsurance for choosing or pricing high-excess layer. Method is supported by extreme value theory. We derive useful estimates of value-at-risk and expected shortfall. We apply this methodology to some fire insurance data.

KRONBORG, MORTEN TOLVER; STEFFENSEN, MOGENS. *Optimal consumption, investment and life insurance with surrender option guarantee*. 59–87. We consider an investor, with an uncertain lifetime, endowed with deterministic labor income, who has the possibility to continuously invest in a Black-Scholes market and to buy life insurance or annuities. We solve the optimal consumption, investment and life insurance problem when the investor is restricted to fulfil an American capital guarantee. By allowing the guarantee to depend, in a very general way, on the past we include, among other possibilities, the interesting case of a minimum rate of return guarantee, commonly offered by pension companies. The optimal strategies turn out to be on option-based portfolio insurance form, but since the capital guarantee is valid at every intermediate point in time, re-calibration is needed whenever the constraint is active.

MATSUI, MUNEYA. *Prediction in a Poisson cluster model with multiple cluster processes*. 1–31. We consider a simple but flexible extension of the Poisson cluster model studied in Matsui & Mikosch (2010) [M. Matsui; T. Mikosch, T. (2010). Prediction in a Poisson cluster model. Journal of Applied Probability 47, 350-366]. In the former, model only a single cluster process starts at each jump point of the Poisson process, whereas we start a randomly given number of cluster processes at each jump. This simple extension yields additional mathematical problems in prediction of future increments of the process which are based on the past observations. However, by making full use of the Poisson structure of the model, we derive reasonably explicit expressions for predictors, which is of critical importance in the insurance application. Some comparisons of predictors are also made by their mean-squared errors when the cluster process is a compound Poisson process. The result yields a natural conclusion that the finer information we use, the better predictors we obtain.

ADAMS, CRAIG J; DONNELLY, CATHERINE; MACDONALD, ANGUS S; FAHRENWALDT, MATTHIAS A. *The impact of known breast cancer polygenes on critical illness insurance*. 141–171. Genetic studies indicate that the inherited risk of breast cancer is mediated by the well-studied major genes BRCA1 and BRCA2, and a polygenic component, probably with many genes each making a small contribution. Recently, seven polygenes have been found contributing an estimated 3.6% of all familial risk. This suggests that the polygenic component may involve well over 100 genetic loci. We extrapolate these new results into a polygenic model with 147 genetic loci and simulate lifetimes of families to calculate the premium ratings appropriate for a family history of breast or ovarian cancer. We model the adverse selection costs arising from restricting the use of genetic test information in critical illness insurance underwriting in light of new European legislation banning the use of gender for insurance underwriting. In this setting, we confirm the overall conclusion of a previous study which used a simpler model that the polygene confers higher adverse selection risk than the BRCA genes. We establish that their three-gene polygenic model does not overly inflate the insurance costs attributable to a polygenic component of breast cancer risk under a model with 147 polygenes.

ALMA, JONAS. *A simulation model for calculating solvency capital requirements for non-life insurance risk*. 107–123. To stay solvent, an insurer must have enough assets to cover its liabilities towards its policy holders. In this paper, we construct a simulation model that is able to generate solvency capital requirements (SCR) for non-life insurance risk. The only input to the model is assumptions about the distributions of payment patterns and ultimate claim amounts. These assumptions should ideally be based on findings in empirical data studies. We illustrate the modelling technique by considering a specific case with motor insurance data from the Swedish insurer Folksam. The SCR values generated by the simulation model with different distributional assumptions in this specific case are analysed and compared to the SCR value calculated using the Solvency II standard model. The most important finding was that the uncertainty in prediction of the trend in ultimate claim amounts affect the SCR substantially. Insurers and supervisory authorities should be aware of the effects of this trend prediction uncertainty when building and evaluating internal models in the Solvency II or other regulatory frameworks.

FAHRENWALDT, MATTHIAS A. *Sensitivity of life insurance reserves via Markov semigroups*. 124–140. We consider Thiele's differential equation for the reserve of a multi-state insurance contract with functional dependence on the surplus. In an analytic approach based on semigroups, we obtain existence and uniqueness results and prove growth and regularity properties. Moreover, we investigate the sensitivity of the reserves with respect to the surplus, payment rate, and transition assumptions in terms of uniform and pointwise estimates. The approach can easily be generalized.

ITSKOVICH, IGOR; ROUDEBUSH, BRADLEY T. *A new parametric model for converting excess mortality from clinical studies to insured population*. 184–199. We propose a new parametric model – the generalized excess mortality (GEM) model – for converting excess mortality from clinical to insured population. The GEM model has been formulated as a generalization of the excess death rate (EDR) model in terms of a single adjustment parameter (m) that accounts for a partial elimination of a clinical study's EDR due to the underwriting selection process.

The suggested value of the parameter m depends only on the ratio of the impairment's prevalence rate in the insured population to that in the clinical population. The model's development has been implemented in two phases: the design phase and the validation phase. In the design phase, the data from the National Health and Nutrition Examination Survey I pertaining to three broad impairments (diabetes, coronary artery disease, and asthma) have been used. As a result, the following equation for the parameter m has been proposed: $m_k = (P_{i,k}/P_{c,k})^n$, where $P_{i,k}$, $P_{c,k}$ are the prevalence rates of impairment k under study in the insured and the clinical populations, respectively, and n a single universal parameter with its value best approximated as $n = 0.5$ (95% confidence interval 0.5–0.6). In the validation phase, several independent clinical studies of three other impairments (Crohn's disease, epilepsy, and chronic obstructive pulmonary disease) were used. As it has been demonstrated in the validation phase, for a number of impairments, the GEM model can provide a better fit for observed insured population mortality than either one of the conventional EDR or mortality ratio models.

LI, JINZHU. *Asymptotics for large claims reinsurance in a time-dependent renewal risk model*. 172–183. We study the asymptotic tail behaviour of reinsured amounts of the LCR and ECOMOR treaties under a time-dependent renewal risk model, in which a dependence structure is introduced between each claim size and the interarrival time before it. Assuming that the claim size distribution has a subexponential tail, we derive some precise asymptotic results for both treaties.

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CHEUNG, KA CHUN; DHAENE, JAN; KUKUSH, ALEXANDER; LINDERS, DANIEL. *Ordered random vectors and equality in distribution*. 221–244. In this paper we show that under appropriate moment conditions, the supermodular ordered random vectors $\underline{X} = (X_1, X_2, \dots, X_n)$ and $\underline{Y} = (Y_1, Y_2, \dots, Y_n)$ with equal expected utilities (or distorted expectations) of the sums $X_1 + X_2 + \dots + X_n$ and $Y_1 + Y_2 + \dots + Y_n$ for an appropriate utility (or distortion) function, must necessarily be equal in distribution, that is $\underline{X} \stackrel{d}{=} \underline{Y}$. The results in this paper can be considered as generalizations of some recent results on comonotonicity, where necessary conditions related to the distribution of $X_1 + X_n + \dots + X_n$ are presented for the random vector $\underline{X} = (X_1, X_2, \dots, X_n)$ to be comonotonic.

FERNÁNDEZ-DURÁN, J J; GREGORIO-DOMÍNGUEZ, M M. *Seasonal mortality for fractional ages in short term life insurance*. 266–277. A uniform distribution of deaths between integral ages is a widely used assumption for estimating future-lifetimes; however, this assumption does not necessarily reflect the true distribution of deaths throughout the year. We propose the use of a seasonal mortality assumption for estimating the distribution of future-lifetimes between integral ages: this assumption accounts for the number of deaths that occurs in given months of the year, including the excess mortality that is observed in winter months. The impact of this seasonal mortality assumption on short-term life insurance premium calculations is then examined by applying the proposed assumption to Mexican mortality data.

KUANG, D; NIELSEN, B; NIELSEN, J P. *The geometric chain-ladder*. 278–300. The log normal reserving model is considered. The contribution of the paper is to derive explicit expressions for the maximum likelihood estimators. These are expressed in terms of development factors which

are geometric averages. The distribution of the estimators is derived. It is shown that the analysis is invariant to traditional measures for exposure.

LI, ZHONGFEI; SENDOVA, KRISTINA P. *On a ruin model with both interclaim times and premiums depending on claim sizes.* 245–265. Under the classical compound Poisson risk model and the Sparre-Andersen risk model, one crucial assumption is that the interclaim times and the claim sizes are independent. However, this assumption might be inappropriate in practice. In this paper, we consider a continuous-time risk process where the interclaim-time distribution and premium rate both depend on the size of the previous claim. Explicit solutions for the Gerber-Shiu discounted penalty function with arbitrary claim-size distribution are derived utilizing the roots of a generalized Lundberg's equation. Applications with exponential thresholds and -family claim sizes are presented. A numerical example is provided.

SCOLLNIK, DAVID P M. *A Pareto scale-inflated outlier model and its Bayesian analysis.* 201–220. This paper develops a Pareto scale-inflated outlier model. This model is intended for use when data from some standard Pareto distribution of interest is suspected to have been contaminated with a relatively small number of outliers from a Pareto distribution with the same shape parameter but with an inflated scale parameter. The Bayesian analysis of this Pareto scale-inflated outlier model is considered and its implementation using the Gibbs sampler is discussed. The paper contains three worked illustrative examples, two of which feature actual insurance claims data.

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FARKAS, JULIA; HASHORVA, ENKELEJD. *Tail approximation for reinsurance portfolios of Gaussian-like risks.* 319–331. We consider two different portfolios of proportional reinsurance of the same pool of risks. This contribution is concerned with Gaussian-like risks, which means that for large values the survival function of such risks is, up to a multiplier, the same as that of a standard Gaussian risk. We establish the tail asymptotic behaviour of the total loss of each of the reinsurance portfolios and determine also the relation between randomly scaled Gaussian-like portfolios and unscaled ones. Further, we show that jointly two portfolios of Gaussian-like risks exhibit asymptotic independence and their weak tail dependence coefficient is nonnegative.

JARNER, SØREN FIIG; MØLLER, THOMAS. *A partial internal model for longevity risk.* 352–382. This paper proposes a simple partial internal model for longevity risk within the Solvency 2 framework. The model is closely linked to the mechanisms associated with the so-called Danish longevity benchmark, where the underlying mortality intensity and the trend is estimated yearly based on mortality experience from the Danish life and pension insurance sector, and on current data from the entire Danish population. Within this model, we derive an estimate for the 99.5% percentile for longevity risk, which differs from the longevity stress of 20% from the standard model. The new stress explicitly reflects the risk associated with unexpected changes in the underlying population mortality intensity on a one-year horizon and with a 99.5% confidence level. In addition, the model contains a component, which quantifies the unsystematic longevity risk associated with a given insurance portfolio. This last component depends on the size of the specific portfolio.

NIE, CIYU; DICKSON, DAVID C M; LI, SHUANMING. *The finite time ruin probability in a risk model with capital injections*. 301–318. We consider a risk model with capital injections. We show that in the Sparre Andersen framework the density of the time to ruin for the model with capital injections can be expressed in terms of the density of the time to ruin in an ordinary Sparre Andersen risk process. In the special case of Erlang inter-claim times and exponential claims, we show that there exists a readily computable formula for the density of the time to ruin. When the inter-claim time distribution is exponential, we obtain an explicit solution for the density of the time to ruin when the individual claim amount distribution is Erlang(2), and we explain techniques to find the moments of the time to ruin. In the final section, we consider the related problem of the distribution of the duration of negative surplus in the classical risk model, and we obtain explicit solutions for the (defective) density of the total duration of negative surplus for two individual claim amount distributions.

PICHLER, ALOIS. *Premiums and reserves, adjusted by distortions*. 332–351. The net premium principle is considered to be the most genuine and fair premium principle in actuarial applications. However, actuarial due diligence requires additional caution in pricing of insurance contracts to avoid, for example, at least bankruptcy of the insurer. This paper addresses the distorted premium principle from various angles. Distorted premiums are typically computed by underweighting or ignoring low, but overweighting high losses. Dual characterizations, which are elaborated in a first part of the paper, support this interpretation. The main contribution consists in an opposite point of view – an alternative characterization – which leaves the probability measure unchanged, but modifies (increases) the outcomes instead in a consistent way. It turns out that this new point of view is natural in actuarial practice, as it can be used for premium calculations, but equally well to determine the reserve process in subsequent years in a time consistent way.

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Variance

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BOOR, JOSEPH A. *Interpolation along a curve*. 9–22. Actuaries quite often have to interpolate data to obtain quantities such as loss development factors (LDFs) for maturities in between the maturities included in a loss development triangle, or increased limits factors for limits between the data points used in the increased limits analysis. This paper presents an approach that includes the advantages of using fitted curves for non-linear data, and that avoids the errors arising from mismatches between patterns in the data and patterns inherent to the curve family used for interpolation.

FU, LUYANG; WANG, HONGYUAN. *Estimating insurance attrition using survival analysis*. 55–72. Retention is an important factor that impacts both profit and growth of insurance companies. Conventional retention analysis, such as logistic regression, does not distinguish between two types of attrition: mid-term cancellation and end-term nonrenewal. In this paper, the authors propose to use survival analysis to estimate attrition and retention. Compared with conventional methods, this approach has three advantages: (1) it addresses not only whether the policy will leave but also when it will leave; (2) it analyzes mid-term cancellation and end-term nonrenewal sequentially, and therefore provides a dynamic insight of retention, which improves the static view

derived from snapshot data; (3) it can take into account time-varying macroeconomic variables, and can help researchers to understand how insurance retention is impacted by the broader economic environment. A case study illustrates the technique, from creating the panel data required by survival analysis to interpreting the model results.

HALLIWELL, LEIGH JOSEPH. *The discrete Fourier transform and cyclical overflow*. 73–79. More casualty actuaries would employ the discrete Fourier transform (DFT) if they understood it better. In addition to the many fine papers on the DFT, this paper might be regarded as just one more introduction. However, the topic uniquely explained herein is how the DFT treats the probability of amounts that overflow its upper bound, a topic that others either have not noticed or have deemed of little importance. The cyclical overflow originates in the modular arithmetic whereby the DFT evaluates characteristic functions. To understand this is to attain a deeper understanding of the DFT, which may lead to its wider use.

HAPP, SEBASTIAN; MAIER, RAMONA; MERZ, MICHAEL. *Multivariate Bühlmann-Straub credibility model applied to claims reserving for correlated run-off triangles*. 23–42. In the present paper we consider the claims reserving problem in a multivariate context. More precisely, we apply the multivariate generalization of the well-known credibility model proposed by Bühlmann and Straub (1970) to claims reserving [H Bühlmann and E Straub, Glaubwürdigkeit für Schadensätze, Bulletin of Swiss Association of Actuaries, 1970, 111-133]. This multi-variate model allows for a simultaneous study of N correlated run-off portfolios and enables the derivation of an estimator for the conditional mean square error of prediction (MSEP) for the credibility predictor of the ultimate claim of the total portfolio. Thereby, we apply multivariate credibility predictors which reflect the correlation structure between the N portfolios and which are optimal in terms of a classical optimality criterion. We illustrate the results by means of an example and compare it to the results derived by the multivariate chain-ladder method and the multivariate additive loss reserving method proposed by Merz and Wüthrich (2008a, b). [M Merz and M V Wüthrich, Prediction error of the chain ladder reserving method applied to correlated run off triangles, *Annals of Actuarial Science* (2008a) 2(1): 25-50] and [M Merz and M V Wüthrich, Prediction error of the multivariate chain ladder reserving method, *North American Actuarial Journal* (2008b) 12(2): 175-197].

PENG, LIANG; WANG, RUODU. *Interval estimation for bivariate t-copulas via Kendall's Tau*. 43–54. Copula models have been popular in risk management. Due to the properties of asymptotic dependence and easy simulation, the t-copula has often been employed in practice. A computationally simple estimation procedure for the t-copula is to first estimate the linear correlation via Kendall's tau estimator and then to estimate the parameter of the number of degrees of freedom by maximizing the pseudo likelihood function. In this paper, we derive the asymptotic limit of this two-step estimator which results in a complicated asymptotic covariance matrix. Further, we propose jackknife empirical likelihood methods to construct confidence intervals/regions for the parameters and the tail dependence coefficient without estimating any additional quantities. A simulation study shows that the proposed methods perform well in finite sample.

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