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ASTIN Bulletin

45(3), 2015

ABDALLAH, ANAS; BOUCHER, JEAN-PHILIPPE; COSSETTE, HELENE. *Modeling dependence between loss triangles with hierarchical archimedean copulas.* 577–599. One of the most critical problems in property/casualty insurance is to determine an appropriate reserve for incurred but unpaid losses. These provisions generally comprise most of the liabilities of a non-life insurance company. The global provisions are often determined under an assumption of independence between the lines of business. Recently, Shi and Frees (2011) proposed to put dependence between lines of business with a copula that captures dependence between two cells of two different runoff triangles. In this paper, we propose to generalize this model in two steps. First, by using an idea proposed by Barnett and Zehnwirth (1998), we will suppose a dependence between all the observations that belong to the same calendar year (CY) for each line of business. Thereafter, we will then suppose another dependence structure that links the CYs of different lines of business. This model is done by using hierarchical Archimedean copulas. We show that the model provides more flexibility than existing models, and offers a better, more realistic and more intuitive interpretation of the dependence between the lines of business. For illustration, the model is applied to a dataset from a major US property-casualty insurer, where a bootstrap method is proposed to estimate the distribution of the reserve.

BOONEN, TIM J. *Competitive equilibria with distortion risk measures.* 703–728. This paper studies optimal risk redistribution between firms, such as banks or insurance companies. The introduction of the Basel II regulation and the Swiss Solvency Test has increased the use of risk measures to evaluate financial or insurance risk. We consider the case where firms use a distortion risk measure (also called dual utility) to evaluate risk. The paper first characterizes all Pareto optimal redistributions. Thereafter, it characterizes all competitive equilibria. It presents three conditions that are jointly sufficient for existence of a unique equilibrium redistribution. This equilibrium's redistribution and prices are provided in closed form via a representative agent.

CHEUNG, KA CHUN; CHONG, WING FUNG; ELLIOT, ROBERT; YAM, SHEUNG CHI PHILLIP. *Disappointment aversion premium principle.* 679–702. In recent years, the determination of premium principle under various non-expected utility frameworks has become popular, such as the pioneer works by Tsanakas and Desli (2003) and Kaluszka and Krzeszowiec (2012). We here revisit the problem under another prevalent behavioral economic theory, namely the

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Disappointment Aversion (DA) Theory proposed by Gul (1991). In this article, we define and study the properties of the DA premium principle, which builds on the equivalent utility premium principle. We derive various properties of this premium principle, such as non-negative and no unjustified risk loading, translation invariance, monotonicity, convexity, positive (non-) homogeneity, independent (non-)additivity, comonotonic (non-)additivity and monotonicity with respect to the extent of disappointment. A generalized Arrow–Pratt approximation is also established. Explicit representations of the premium principle are obtained for linear and exponential utilities, and they reveal that the premium principle proposed echoes the capital reserve regulatory requirement in practice.

CHRISTIANSEN, MARCUS C; SPODAREVA, EVGENY; UNSELDA, VERENA. *Differences in European mortality rates: a geometric approach on the age–period plane.* 477–502. Age and period are the most widely used parameters for forecasting mortality rates. Empirical mortality rate differences in multiple populations often show strong geometric patterns on the two-dimensional age–period plane. The idea of this paper is to take these geometric patterns as the starting point for the development of forecasts. A parametric approach is presented and discussed which uses simple techniques from spatial statistics. The proposed model is statistically parsimonious and yields forecasts that are consistent with the historical data and coherent for multiple populations.

DEVOLDER, PIERRE; MELIS, ROBERTA. *Optimal mix between pay as you go framework and funding for pension liabilities in a stochastic framework.* 551–575. This paper addresses the financing of public pensions in a stochastic environment. Traditionally, funded and unfunded pension schemes have been viewed as opposite solutions for the first pillar of public pensions. However, more recently countries as Sweden and Poland have explored mixed solutions that combine pay-as-you-go (PAYG) with funding mechanisms. The aims of this paper are to examine the rationality of such a combination using portfolio theory arguments and to find the optimal split of the contributions between the two systems. We first introduce the classical deterministic model leading to the well-known Samuelson–Aaron rule according to which diversification is never optimal. We then introduce different stochastic models in which the main processes (wage growth, population growth, financial rate of return) are random. In particular, we obtain conditions on parameters to justify diversification and explicit optimal sharing between PAYG and funding. We also introduce the possibility of investing in several financial assets and explore the impact of introducing systematic longevity risk.

DONG, ALICE X D; CHAN, JENNIFER S K; PETERS, GARETH W. *Risk margin quantile function via parametric and non-parametric bayesian approaches.* 503–550. We develop quantile functions from regression models in order to derive risk margin and to evaluate capital in non-life insurance applications. By utilizing the entire range of conditional quantile functions, especially higher quantile levels, we detail how quantile regression is capable of providing an accurate estimation of risk margin and an overview of implied capital based on the historical volatility of a general insurers loss portfolio. Two modeling frameworks are considered based around parametric and non-parametric regression models which we develop specifically in this insurance setting. In the parametric framework, quantile functions are derived using several distributions including the flexible generalized beta (GB2) distribution family, asymmetric Laplace (AL) distribution and power-Pareto (PP) distribution. In these parametric model based quantile regressions, we detail two basic formulations. The first involves embedding the quantile regression loss function from the nonparameteric setting into the argument of the kernel of a parametric data likelihood model, this

is well known to naturally lead to the AL parametric model case. The second formulation we utilize in the parametric setting adopts an alternative quantile regression formulation in which we assume a structural expression for the regression trend and volatility functions which act to modify a base quantile function in order to produce the conditional data quantile function. This second approach allows a range of flexible parametric models to be considered with different tail behaviors. We demonstrate how to perform estimation of the resulting parametric models under a Bayesian regression framework. To achieve this, we design Markov chain Monte Carlo (MCMC) sampling strategies for the resulting Bayesian posterior quantile regression models. In the non-parametric framework, we construct quantile functions by minimizing an asymmetrically weighted loss function and estimate the parameters under the AL proxy distribution to resemble the minimization process. This quantile regression model is contrasted to the parametric AL mean regression model and both are expressed as a scale mixture of uniform distributions to facilitate efficient implementation. The models are extended to adopt dynamic mean, variance and skewness and applied to analyze two real loss reserve data sets to perform inference and discuss interesting features of quantile regression for risk margin calculations.

FURMAN, EDWARD; SU, JIANXI; ZITIKIS, RICARDAS. *Paths and indices of maximal tail dependence*. 661–678. We demonstrate both analytically and numerically that the existing methods for measuring tail dependence in copulas may sometimes underestimate the extent of extreme co-movements of dependent risks and, therefore, may not always comply with the new paradigm of prudent risk management. This phenomenon holds in the context of both symmetric and asymmetric copulas with and without singularities. As a remedy, we introduce a notion of paths of maximal (tail) dependence and utilize the notion to propose several new indices of tail dependence. The suggested new indices are conservative, conform with the basic concepts of modern quantitative risk management, and are capable of differentiating between distinct risky positions in situations when the existing indices fail to do so.

GÓMEZ DÉNIZ, EMILIO; CALDERÍN-OJEDA, ENRIQUE. *Modelling insurance data with the pareto arctan distribution*. 639–660. In this paper, a new methodology based on the use of the inverse of the circular tangent function that allows us to add a scale parameter (say a) to an initial survival function is presented. The latter survival function is determined as limiting case when a tends to zero. By choosing as parent the classical Pareto survival function, the Pareto ArcTan (PAT) distribution is obtained. After providing a comprehensive analysis of its statistical properties, theoretical results with reference to insurance are illustrated. Its performance is compared, by means of the well-known Norwegian fire insurance data, with other existing heavy-tailed distributions in the literature such as Pareto, Stoppa, Shifted Lognormal, Inverse Gamma and Fréchet distributions.

SERI, RAFFAELLO; CHOIRAT, CHRISTINE. *Comparison of approximations for compound poisson processes*. 601–637. In this paper, we compare the error in several approximation methods for the cumulative aggregate claim distribution customarily used in the collective model of insurance theory. In this model, it is usually supposed that a portfolio is at risk for a time period of length t. The occurrences of the claims are governed by a Poisson process of intensity μ so that the number of claims in [0,t] is a Poisson random variable with parameter = μ t. Each single claim is an independent replication of the random variable X, representing the claim severity. The aggregate claim or total claim amount process in [0,t] is represented by the random sum of N independent replications of X, whose cumulative distribution function (cdf) is the object of study. Due to its computational complexity, several approximation methods for this cdf have been proposed.

In this paper, we consider 15 approximations put forward in the literature that only use information on the lower order moments of the involved distributions. For each approximation, we consider the difference between the true distribution and the approximating one and we propose to use expansions of this difference related to Edgeworth series to measure their accuracy as $= \mu\, t$ diverges to infinity. Using these expansions, several statements concerning the quality of approximations for the distribution of the aggregate claim process can find theoretical support. Other statements can be disproved on the same grounds. Finally, we investigate numerically the accuracy of the proposed formulas.

VERBELEN, ROEL; GONG, LAN; ANTONIO, KATRIEN; BADESCU, ANDREI; LIN, SHELDON. *Fitting mixtures of erlangs to censored and truncated data using the EM algorithm.* 729–758. We discuss how to fit mixtures of Erlangs to censored and truncated data by iteratively using the EM algorithm. Mixtures of Erlangs form a very versatile, yet analytically tractable, class of distributions making them suitable for loss modeling purposes. The effectiveness of the proposed algorithm is demonstrated on simulated data as well as real data sets.

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European Actuarial Journal

5(2), 2015

ANTONIO, KATRIEN; BARDOUTSOS, ANASTASIOS; OUBURG, WILBERT. *Bayesian Poisson log-bilinear models for mortality projections with multiple populations.* 245–281. Life insurers, pension funds, health care providers and social security institutions face increasing expenses due to continuing improvements of mortality rates. The actuarial and demographic literature has introduced a myriad of (deterministic and stochastic) models to forecast mortality rates of single populations. This paper presents a Bayesian analysis of two related multi-population mortality models of log-bilinear type, designed for two or more populations. Using a larger set of data, multi-population mortality models allow joint modelling and projection of mortality rates by identifying characteristics shared by all sub-populations as well as sub-population specific effects on mortality. This is important when modeling and forecasting mortality of males and females, regions within a country and when dealing with index-based longevity hedges. Our first model is inspired by the two factor Lee–Carter model of Renshaw and Haberman (Insurance Mathematics and Economics (2003) 33(2): 255–272) and the common factor model of Carter and Lee (International Journal of Forecast (1992) 8:393–411). The second model is the augmented common factor model of Li and Lee (Demography (2005) 42(3): 575–594). This paper approaches both

models in a statistical way, using a Poisson distribution for the number of deaths at a certain age and in a certain time period. Moreover, we use Bayesian statistics to calibrate the models and to produce mortality forecasts. We develop the technicalities necessary for Markov Chain Monte Carlo ([MCMC]) simulations and provide software implementation (in R) for the models discussed in the paper. Key benefits of this approach are multiple. We jointly calibrate the Poisson likelihood for the number of deaths and the times series models imposed on the time dependent parameters, we enable full allowance for parameter uncertainty and we are able to handle missing data as well as small sample populations. We compare and contrast results from both models to the results obtained with a frequentist single population approach and a least squares estimation of the augmented common factor model.

BEN-SALAH, ZIED; GUÉRIN, HÉLÈNE; MORALES, MANUEL. *On the depletion problem for an insurance risk process: new non-ruin quantities in collective risk theory.* 381–425. The field of risk theory has traditionally focused on ruin-related quantities. In particular, the so-called expected discounted penalty function (Gerber and Shiu. North American Actuarial Journal (1998) 2(1): 48–78) has been the object of a thorough study over the years. Although interesting in their own right, ruin related quantities do not seem to capture path-dependent properties of the reserve. In this article we aim at presenting the probabilistic properties of drawdowns and the speed at which an insurance reserve depletes as a consequence of the risk exposure of the company. These new quantities are not ruin related yet they capture important features of an insurance position and we believe it can lead to the design of a meaningful risk measures. Studying drawdowns and speed of depletion for Lévy insurance risk processes represent a novel and challenging concept in insurance mathematics. In this paper, all these concepts are formally introduced in an insurance setting. Moreover, we specialize recent results in fluctuation theory for Lévy processes (Mijatovic and Pistorius. Stochastic Processes and Their Application (2012) 22: 3812–3836) in order to derive expressions for the distribution of several quantities related to the depletion problem. Of particular interest are the distribution of drawdowns and the Laplace transform for the speed of depletion. These expressions are given for several examples of Lévy insurance risk processes for which they can be calculated, in particular for the classical Cramér-Lundberg model.

BURKHART, TOBIAS; REUß, ANDREAS; ZWIESLER, HANS-JOACHIM. *Participating life insurance contracts under Solvency II: inheritance effects and allowance for a Going Concern Reserve.* 203–244. Some details of the Solvency II framework are still under discussion. A crucial aspect in the debate is the appropriate reflection of surplus participation mechanisms that apply to traditional participating life insurance contracts. In particular, the inheritance of profits between existing business and new business resulting from the surplus participation process has to be incorporated in the Solvency II valuation framework which requires a run off valuation of the existing portfolio under going concern assumptions. This paper analyzes the inheritance effects caused by the pre-financing of acquisition cost of new business via cost surplus of existing business which is inherent in traditional German life insurance. We show that in the context of Solvency II an allowance for the inherited funds – denoted as Going Concern Reserve (GCR) – is justified and in line with the Solvency II valuation principles. Based on a stochastic balance sheet and cash flow projection model, we present a methodology to quantify the GCR and provide a profound analysis of the GCR and its components. Our results show that the GCR has significant impact on the overall solvency situation of life insurance companies offering participating contracts.

FLEISCHMANN, ANSELM. *Calibrating intensities for long-term care multiple-state Markov insurance model.* 327–354. Multiple-state Markov models for life or health insurance have been

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studied for a considerable amount of time (Christiansen, in Multiple-state models in health insurance, 2012; Helwich, in Durational effects and non-smooth semi-Markov models in life insurance, 2008; Koller, in Stochastische Modelle in der Lebensversicherung, 2000). Given the ease and straight forward way of modelling complex tariffs within the modelling framework of multiple-state Markov models it is surprising to observe that these models still await wide-spread use. Having introduced tariffs for private, supplementary long-term care insurance in the Austrian private health insurance market, the biggest obstacle for using a multiple-state Markov model has been its calibration of the underlying state-change intensities to empirical data. These difficulties were addressed by developing and applying a method to extract state-change intensities from published empirical observations of prevalence rates under assumptions that were deemed sufficient for a portfolio of contracts providing recurring payments dependent on degree of severity of long-term care need. The method developed is described in detail, the used empirical data and derived results are given. This paper is intended to foster further discussion and research regarding calibration methods for advanced insurance models.

GAO, HUAN; MAMON, ROGEMAR; LIU, XIAOMING. *Pricing a guaranteed annuity option under correlated and regime-switching risk factors*. 309–326. A Markov-modulated affine framework for dependent risk factors is proposed to value a guaranteed annuity option (GAO). Concentrating on the important effect of volatilities, both diffusion components of the interest and mortality rates are driven by a finite-state continuous time Markov chain. We derive an explicit solution to the price of a pure endowment by solving a system of linear ordinary differential equations with the aid of the forward measure. Utilising the endowment-risk-adjusted measure with pure endowment as the corresponding numéraire, we provide an efficient and accurate formula in obtaining the GAO price. Such valuation efficiency and accuracy were demonstrated through numerical experiments. We benchmark our results with those of the Monte-Carlo simulation method and show significant differences in standard errors and computing times.

PENG, LIANG; WANG, XING; ZHENG, YANTING. *Empirical likelihood inference for Haezendonck-Goovaerts risk measure*. 427–445. Recently Haezendonck-Goovaerts risk measure is receiving much attention in actuarial science with applications in the study of optimal portfolio and optimal reinsurance policy. Nonparametric estimation is proposed by Ahn and Shyamalkumar (2014) [Insurance Mathematics and Economics (2014) 55: 78–90], where the derived asymptotic limit can be employed to construct an interval for the Haezendonck-Goovaerts risk measure. In this paper, we propose an alternative empirical likelihood inference for this risk measure. A simulation study shows the good performance of the proposed method.

TÅGHOLT GAD, KAMILLE SOFIE; JUHL, JEPPE; STEFFENSEN, MOGENS. *Reserve-dependent surrender rates*. 283–308. We study the modelling and valuation of surrender and other behavioural options in life insurance and pension. We place ourselves in between the two extremes of optimal and arbitrary interventions by the policyholders. We present a model where one single parameter reflects the extent of rationality among policyholders. This presentation includes conditions which ensure that when the parameter goes to infinity contract values converge to the values corresponding to policyholders exhibiting optimal behaviour. When expenses are taken into account we lose the duality between the policyholder's valuation of the contract and what we speak of as the market reserve. We include this in our model, and we give an upper bound for the difference between the value when the policyholder behaves optimally from her own point of view and the worst case market reserve from the pension fund point of view. In a series of numerical examples we illustrate the impact of the rationality parameter on the contract values.

TERZIOGLU, M KENAN; SUCU, MERAL. *Gompertz-Makeham parameter estimations and valuation approaches: Turkish life insurance sector.* 447–468. For participating life insurance, the objective of insurance companies is to control the investments of policyholders by considering changing market conditions within the scope of risk management and increase their returns. Given that insurance companies compete in the market with participating life insurance, insurers and academicians attempt to develop this product. This paper compares net premium valuation and paid-up valuation methods used in the valuation of participating life insurance contracts in Turkey. The development of a single endowment policy with a level premium payment has been modeled as a time-continuous Markov chain model. Mortality in Turkey has been determined by calculating the parameter values of the Gompertz-Makeham function. It has been observed that insurance companies would not face valuation losses using the paid-up valuation method, even though policyholders stopped premium payments before the policy term. Moreover, compared with other valuation methods, the paid-up valuation method has been found to offer freedom of investment.

VERRALL, RICHARD J; WÜTHRICH, MARIO V. *Parameter reduction in log-normal chain-ladder models.* 355–380. Multiplicative chain-ladder (CL) models are characterized by CL factors that explain the development of claims from one period to the next. In classical CL models every development period has its own CL factor. In the present paper we give a method describing how some of these CL factors can be modeled by a joint functional dependence. This joint functional form reduces the number of model parameters needed.

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ALHASSAN, ABDUL LATIF; BIEKPE, NICHOLAS. *Efficiency, productivity and returns to scale economies in the non-life Insurance market in South Africa.* 493–515. This paper undertakes a comprehensive analysis of efficiency, productivity and returns to scale economies in the non-life insurance market in South Africa from 2007 to 2012. The data envelopment analysis technique is employed to estimate efficiency and returns to scale while productivity growth is analysed with the Malmquist index. Truncated bootstrapped regression and logistic regression techniques are used to identify the determinants of efficiency and the probability of operating under constant returns to scale. The results indicate that non-life insurers operate with about 50 per cent inefficiencies, while about 20 per cent of insurers operate at an optimal scale. We also observe productivity improvements attributable to technological changes. The results of the regression analysis reveal a non-linear effect of size on efficiency and constant returns to scale. Product line diversification, reinsurance and leverage also have a significant relationship with efficiency and constant returns to scale. A major contribution of this paper is the analysis of efficiency convergence using the growth convergence theory. Implications for management and industry regulation are drawn from the findings.

BERDIN, ELIA; GRÜNDL, HELMUT. *The effects of a low interest rate environment on life insurers.* 385–415. Low interest rates are becoming a threat to the stability of the life insurance

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industry, especially in countries such as Germany, where products with relatively high guaranteed returns sold in the past still represent a prominent share of the total portfolio. This contribution aims to assess and quantify the effects of the current low interest rate phase on the balance sheet of a representative German life insurer, given the current asset allocation and the outstanding liabilities. To do this, we generate a stochastic term structure of interest rates as well as stock market returns to simulate investment returns of a stylised life insurance business portfolio in a multi-period setting. On the basis of empirically calibrated parameters, we can observe the evolution of the life insurers' balance sheet over time with a special focus on their solvency situation. To account for different scenarios and in order to check the robustness of our findings, we calibrate different capital market settings and different initial situations of capital endowment. Our results suggest that a prolonged period of low interest rates would markedly affect the solvency situation of life insurers, leading to a relatively high cumulative probability of default, especially for less capitalised companies. In addition, the new reform of the German life insurance regulation has a beneficial effect on the cumulative probability of default, as a direct consequence of the reduction of payouts to policyholders.

BOYER, M MARTIN; DUPONT-COURTADE, THÉODORA. *The structure of reinsurance contracts*. 474–492. Using a unique proprietary data set of primary insurers and reinsurers, we analyse the structure of the reinsurance market. The data, which spans six years, contains the quotes for different reinsurance layers, for different clients, for different treaties and for different lines of business. This is the first study that documents the actual structure of the global reinsurance market using actual quotes, not just the winning quote, for a large number of layers and a large number of reinsurance treaties.

CHEN, LEON; POTTIER, STEVEN W. *The relative informativeness of analysts' stock return forecasts and rating changes for insurance companies*. 516–537. Stock return forecasts and financial strength ratings are supposed to represent concise and complete summary measures of the financial prospects of publicly traded insurance companies. The key questions for investors and other parties who may choose to rely on these metrics are whether they help predict actual stock returns and the relative informativeness of each metric. Ours is the first study to provide empirical evidence on these questions for insurers. Our forecasted stock returns are computed from target stock prices, which represent an explicit estimate of a firm's future market value. We find that the mean 12-month-ahead (forecasted) stock return in our sample is around 20 per cent, while the actual mean annualised stock return is around 10 per cent, suggesting analysts' optimism, inaccuracy, or some of both. Current period forecasted stock returns are positively correlated with past forecasted stock returns, and negatively correlated with past actual stock returns. Current period forecasted stock returns exhibit a strong positive association with future period actual stock returns, suggesting that forecasted stock returns are useful predictors of future actual stock returns. Furthermore, an increase in actual or forecasted stock returns decreases the likelihood of a rating downgrade, but has little relation to rating upgrades. These results support the usefulness of stock return forecasts to investors and rating agents.

CUMMINS, J DAVID; KLUMPES, PAUL; WEISS, MARY A. *Mergers and acquisitions in the global insurance industry: valuation effects*. 444–473. This paper examines whether global insurance mergers and acquisitions (M&As) create value for shareholders by conducting an event study of M&A transactions for the period 1990–2006. In the overall sample, insurance acquirers realised small positive cumulative average abnormal returns (CAARs), whereas targets realised substantial positive CAARs. Both cross-border and within-border transactions led to substantial value

creation for targets. Market value gains for acquirers are centred in the U.S. and Europe; acquirer CAARs for Asian M&As are mostly insignificant. Targets realise significant market value gains in the U.S., Europe and Asia, with the largest gains for U.S. transactions. Acquirers from the insurance industry realise small market value gains from within-industry transactions, but cross-industry M&As are value-neutral. Targets realise significant market value gains in both cross- and within-industry transactions, but the within-industry gains are significantly larger. The results suggest that insurers should concentrate on focusing rather than diversifying transactions.

ECKLES, DAVID L; HILLIARD, JAMES I. *Government intervention through an implicit federal backstop: is there a link to market power?* 538–555. We estimate the impact of exogenous capital shocks, namely the Troubled Asset Relief Program (TARP), on prices in various property-casualty business lines. We hypothesise that these capital shocks may distort insurer incentives. Specifically, insurers may exploit the implicit governmental guaranty by taking additional pricing risks in order to gain market share. Our results do not support this hypothesis. We find no evidence of a company-specific, or industry-wide, moral hazard problem associated with the implicit (explicit, in some cases) federal backstop created by TARP funds.

NIEDER, DIRK; GRÜNDL, HELMUT. *The effects of contingent convertible (CoCo) bonds on insurers' capital requirements Under Solvency II.* 416–443. The Liikanen Group proposes contingent convertible (CoCo) bonds as a potential mechanism to enhance financial stability in the banking industry. Especially life insurance companies could serve as CoCo bond holders, as they are already the largest purchasers of bank bonds in Europe. We develop a stylised model with a direct financial connection between banking and insurance and study the effects of various types of bonds such as non-convertible bonds, write-down bonds and CoCos on banks' and insurers' risk situations. In addition, we compare insurers' capital requirements under the proposed Solvency II standard model as well as under an internal model that ex ante anticipates additional risks due to possible conversion of the CoCo bond into bank shares. In order to check the robustness of our findings, we consider different CoCo designs (write-down factor, trigger value, holding time of bank shares) and compare the resulting capital requirements with those for holding non-convertible bonds. We identify situations in which insurers benefit from buying CoCo bonds due to lower capital requirements and higher coupon rates. Furthermore, our results highlight how the Solvency II standard model can mislead insurers in their CoCo investment decision due to economically irrational incentives.

THIMANN, CHRISTINE. *Systemic features of insurance and banking, and the role of leverage, capital and loss absorption.* 359–384. This paper aims at providing a conceptual distinction between banking and insurance with regard to systemic regulation. It discusses key differences and similarities as to how both sectors interact with the financial system. Insurers interact as financial intermediaries and through financial market investments, but do not share the features of banking that give rise to particular systemic risk in that sector, such as the institutional interconnectedness through the interbank market, the maturity transformation combined with leverage, the prevalence of liquidity risk and the process of money creation. The paper also draws attention to three salient features in insurance that need to be taken into account in systemic regulation: the quasi-absence of leverage, the fundamentally different role of capital and the "built-in bail-in" of a significant part of insurance liabilities through policyholder participation. Based on these considerations, the paper argues that, if certain activities were to give rise to concerns about systemic risk in the case of insurers, regulatory responses other than capital surcharges may be more appropriate.

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COLE, SHAWN. *Overcoming barriers to microinsurance adoption: evidence from the field.* 720–740. This paper provides an overview of the academic literature on microinsurance adoption in emerging markets, with a particular emphasis on randomised control trials. I discuss what we know, what we can reasonably hope to know using the extensive work on microcredit as a comparator, and what the available evidence implies for public policy. Particular attention is paid to the case for a greater role for the government in supporting the development of microinsurance.

HONG, SHI; BAO, SHIZHE. *Guaranty funds, government shareholding and risk taking: evidence from China.* 653–677. This study examines the risk-subsidy, monitoring and ownership structure hypotheses in relation to guaranty funds using a sample from the Chinese insurance industry. Compared to the American model, Chinese insurance guaranty funds possess the following distinct features: pre-assessment, separate accumulation and partial responsibility for peer bankruptcy. We find that the risks of insurance firms decline following the establishment of guaranty funds. Pre-assessment provides a limited risk incentive to insurers and one that is easily offset by stakeholder monitoring. In terms of the ownership structure hypothesis, we find that foreign insurers are more risk-driven than their state-controlled counterparts. Our findings have implications for countries striving to lessen the adverse effect of guaranty funds as well as for the improvement of insurance regulation policy in China.

HSIEH, MENG-FEN; LEE, CHIEN-CHIANG; YANG, SHIH-JUI. The impact of diversification on performance in the insurance industry: the roles of globalisation, financial reforms and global crisis. 585–631. This paper builds on the diversity-performance relation in the cross-country literature by examining the property-liability insurance industry across 62 countries. It is, to the best of our knowledge, the first paper to explore the heterogeneity across countries over time by utilising the dynamic panel generalised method of moments approach, thus connecting directly with the current debates on the diversity-performance relation. The results show that a higher level of diversification leads to higher returns and insurers' risk, while intending to decrease the degree of leverage. Furthermore, globalisation and financial reforms have more significant impacts on performance in non-high-income countries. The results indicate that income diversity can improve an insurer's performance under the condition of financial reforms, but liberalisation with direct credit and interest rate control variables leads to higher competition and erodes an insurer's profitability. During global crisis periods, insurers in high-income countries that are well diversified are able to adjust their leverage ratio faster than insurers in non-high-income countries.

JENG, VIVIAN S C. *Competition and Its variation over time: an empirical analysis of the Chinese insurance industry.* 632–652. We use Chinese insurance market data for the period 2001–2009 to examine the degree of competition in the life and property-liability insurance industries. We show that, during the period 2001–2002, the Chinese life insurance market was under a monopoly, but it has been operating under monopolistic competition since 2003. By contrast, the property-liability insurance market was under a monopoly for the full time period. In addition, our results show that domestic firms compete more actively than foreign firms, and among foreign insurers, there is a clear structural break between firms that have expanded and those that have not. This difference is especially obvious in the property-liability insurance industry. We thus suggest that an

implicit geographic restriction could be one of the reasons that foreign firms in China are placed in an inferior position when competing with domestic firms.

KUNREUTHER, HOWARD C. *The role of insurance in reducing losses from extreme events: the need for public-private partnerships.* 741–762. This paper describes the challenges that consumers, insurers and insurance regulators face in dealing with insurance for low-probability, high-consequence events. Given their limited experience with catastrophes, there is a tendency for all three parties often to engage in short-term intuitive thinking rather than long-term deliberative thinking when making these insurance-related decisions. Public-private partnerships can encourage investment in protective measures prior to a disaster, deal with affordability problems and provide coverage for catastrophic risks. Insurance premiums based on risk provide signals to residents and businesses as to the hazards they face and enable insurers to lower premiums for properties where steps have been taken to reduce risk. To address issues of equity and fairness, homeowners who cannot afford insurance could be given vouchers tied to loans for investing in loss reduction measures. The National Flood Insurance Program provides an opportunity to implement a public-private partnership that could eventually be extended to other extreme events.

PETRESKI, BLAGICA. *Empirical analysis of the risks and resilience to shocks of the Macedonian insurance sector.* 678–700. The objective of this paper is to analyse the risks to the stability of the Macedonian insurance sector and to quantify its resilience to shocks. In the empirical economic model, insurance sector stability, as measured through the log of the solvency margin, is a function of total claims settled in total gross premiums, market concentration, product concentration, deposit interest rates, inflation rate and GDP growth. The analysis covers all 11 non-life insurance companies over the period from 2008:Q4 to 2014:Q2, using panel methods and Monte Carlo simulation. The results suggest that only claims settled as a measure of individual insurance risks and the inflation rate as a measure of market risks affect the stability of the Macedonian insurance sector. Stress simulations indicate that the Macedonian insurance sector remains robust even under extreme shocks. However, the stress tests of the individual companies reveal that 3 out of 11 companies fail the stress test.

SCHMAULTZ, MATTHIAS. *Value creation and solvency: a simple approach to deriving a non-life insurer's optimal growth strategy.* 701–719. Strategic planning in non-life insurance companies must consider differing demands from the company's various stakeholders. While investors and shareholders require growth in equity market value, rating agencies, costumers and the authorities focus on the company's solvency, that is, the amount of capital covering the business risks. In that regard, growth in premium income and business profitability are critical, but opposing drivers for operative management. In this article, we model profitability in the insurance business in dependence on premium growth and analyse the impact of the underlying growth strategy on shareholder value and solvency for a non-life insurance company. In a multi-period framework, we find that an optimal growth strategy, maximising net present value and fulfilling a solvency constraint can be derived in dependence on the initial insurance portfolio mix of new and renewal business. The results of the analysis further demonstrate that higher growth rates can lead to lower equity values and vice versa, and that the solvency constraint can prohibit a shareholder-value-maximising strategy. Therefore, the approach is useful in supporting strategic decision-taking and value-based management in non-life insurance companies.

STECHEMESSER, KRISTIN; ENDRIKAT, JAN; GRASSHOFF, NICO; GUENTHER, EDELTRAUD. *Insurance companies' responses to climate change: adaptation, dynamic*

capabilities and competitive advantage. 557–584. Drawing on the dynamic capability view, we analyse how insurers adapt to climate change impacts and how adaptation relates to corporate financial performance. Based on a comprehensive literature review, we deduce seven categories of adaptation measures associated with three dynamic capability dimensions of climate change adaptation (i.e. climate knowledge absorption, climate-related operational flexibility and strategic climate integration). Using this framework, we conduct a content analysis of insurers' adaptation efforts as reported to the Carbon Disclosure Project. Regression analysis reveals positive relationships between climate knowledge absorption and return on assets (ROA), climate-related operational flexibility and ROA, and between the total number of adaptation measures and ROA.

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BAJTELSMIT, VICKIE; THISTLE, PAUL. *Liability, insurance and the incentive to obtain information about risk.* 171–193. We examine the incentives to obtain information about risk under strict liability and negligence rules when insurance is available. Information helps reduce the expected cost of accidents, but also exposes the potential injurer to classification risk. As a result, the social value of information may be negative. Under both strict liability and negligence, the private value of information may also be negative when insurance is available.

FONG, JOELLE H. *Beyond age and sex: enhancing annuity pricing.* 133–170. This paper examines the use of more extensive risk classification and its impact on annuitisation values in consumer markets with mortality heterogeneity. Prices of U.S. retail annuities do not currently reflect buyers' attributes other than age and sex. I qualitatively assess a number of proposed underwriting factors and show that the factors chosen can robustly predict mortality heterogeneity in a hazards framework. The relative value of annuities across demographic groups converges considerably under finer-grained pricing, but the change in consumers' well-being is asymmetric. Shorter-lived annuitants gain about 30 per cent in financial and utility-adjusted terms, whereas longer-lived annuitants experience losses of 16 per cent.

HOY, MIKE; TREICH, NICOLAS. *Geneva Risk and Insurance Review 40th Anniversary Issue.* 89–96. This year, The Geneva Papers is celebrating 40 years of existence. This is a great occasion to look back and see what has been accomplished. In order to help celebrate this 40th anniversary, Palgrave decided to edit a special anniversary issue of The Geneva Risk and Insurance Review (GRIR). As the current GRIR co-editors-in-chief, we were asked to select a list of about 10 papers published in the journal to appear in this special issue.

LOUBERGÉ, HENRI. *From The Geneva Papers on Risk and Insurance to The Geneva Risk and Insurance Review.* 97–101. The Geneva Risk and Insurance Review celebrates in 2016 its 40th year of existence. Yes. But it must be recalled that about half of these 40 years occurred under

a different name—The Geneva Papers on Risk and Insurance. For a long time, the fate of the journal was very closely linked to the development of "The Geneva Association".

PENG, JIN-LUNG; WANG, KILI C. Information problems in bancassurance: Empirical evidence based on a comparison between over-the-counter and telephone marketing customers. 102–132. We investigate the problem of asymmetric information among the different distribution channels of bancassurance, namely, over-the-counter (OTC) selling and telephone marketing (TM). We predict that the bank could bring an information advantage to insurance companies through TM by providing a customer list based on the customers' records in the bank. Bancassurance can play a role of integrating the information that is transferred from the bank to the insurance company. Our empirical evidence shows that, in contrast to OTC customers, there is less evidence of adverse selection, and there is also less evidence of moral hazard or fraud among the TM customers that have been sorted by the bank. This phenomenon could be attributed to the valuable private information provided by the credit records of customers kept by the bank.

Insurance: Mathematics & Economics

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AI, JING; BROCKETT, PATRICK L; JACOBSON, ALLEN F. *A new defined benefit pension risk measurement methodology.* 40–51. Defined benefit pension plan sponsors have taken on greater risks for sponsoring these plans in the last several years. Due to ever increasing concerns of longevity risk and the weak economic environment, sponsors are eager to understand their pension-related risks to facilitate optimal enterprise decision-making. Borrowing an analytical framework from the life insurance and annuity industry where the amount of risk is framed in terms of the total assets required to remain solvent over a one-year period with a high level of confidence, i.e., the economic capital approach, this paper develops a benchmark risk measure for pension sponsors by obtaining a total asset requirement for sustaining the pension plan. The difference between the total asset requirement and the actual trust assets thus provides a measure of sponsor assets at risk due to plan sponsorship. Two factor-based approaches are proposed for this calculation. The first approach develops a set of pension-specific factors as if the pension plan were a group annuity. The second approach directly simulates the risk drivers of the pension plan and develops a framework for obtaining factors and calculating the pension risk given a desired confidence level. Our approach is very easy to implement and monitor in practice.

CHEN, HUA; MACMINN, RICHARD; SUN, TAO. *Multi-population mortality models: a factor copula approach.* 135–146. Modeling mortality co-movements for multiple populations have significant implications for mortality/longevity risk management. A few two-population mortality models have been proposed to date. They are typically based on the assumption that the forecasted mortality experiences of two or more related populations converge in the long run. This assumption might be justified by the long-term mortality co-integration and thus be applicable to

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longevity risk modeling. However, it seems too strong to model the short-term mortality dependence. In this paper, we propose a two-stage procedure based on the time series analysis and a factor copula approach to model mortality dependence for multiple populations. In the first stage, we filter the mortality dynamics of each population using an ARMA-GARCH process with heavy-tailed innovations. In the second stage, we model the residual risk using a one-factor copula model that is widely applicable to high dimension data and very flexible in terms of model specification. We then illustrate how to use our mortality model and the maximum entropy approach for mortality risk pricing and hedging. Our model generates par spreads that are very close to the actual spreads of the Vita III mortality bond. We also propose a longevity trend bond and demonstrate how to use this bond to hedge residual longevity risk of an insurer with both annuity and life books of business.

GAO, HUAN; MAMON, ROGEMAR; LIU, XIAOMING; TENYAKOV, ANTON. *Mortality modelling with regime-switching for the valuation of a guaranteed annuity option.* 108–120. We consider three ways of putting forward a regime-switching approach in modelling the evolution of mortality rates for the purpose of pricing a guaranteed annuity option (GAO). This involves the extension of the Gompertz and non-mean reverting models as well as the adoption of a pure Markov model for the force of mortality. A continuous-time finite-state Markov chain is employed to describe the evolution of mortality model parameters which are then estimated using the filtered-based and least-squares methods. The adequacy of the regime-switching Gompertz model for the US mortality data is demonstrated via the goodness-of-fit metrics and likelihood-based selection criteria. A GAO is valued assuming the interest and mortality risk factors are switching regimes in accordance with the dynamics of two independent Markov chains. To obtain closed-form valuation formulae, we employ the change of measure technique with the pure endowment price as the numéraire. Numerical implementations are included to compare the results of the proposed approaches and those from the Monte Carlo simulations.

GOURIEROUX, CHRISTIAN; LU, YANG. *Love and death: a Freund model with frailty.* 191–203. We introduce new models for analyzing the mortality dependence between individuals in a couple. The mortality risk dependence is usually taken into account in the actuarial literature by introducing special copulas with continuous density. This practice implies symmetric effects on the remaining lifetime of the surviving spouse. The new model allows for both asymmetric reactions by means of a Freund model, and risk dependence by means of an unobservable common risk factor (or frailty). These models allow for distinguishing in the lifetime dependence the component due to common lifetime (frailty) from the jump in mortality intensity upon death of spouse (Freund model). The model is applied to the pricing of insurance products such as joint life policy, last survivor insurance, or contracts with reversionary annuities. A discussion of identification is also provided.

HORNEFF, VANYA; MAURER, RAIMOND; MITCHELL, OLIVIA S; ROGALLA, RALPH. *Optimal life cycle portfolio choice with variable annuities offering liquidity and investment downside protection.* 91–107. This paper assesses optimal life cycle consumption and portfolio allocations when households have access to Guaranteed Minimum Withdrawal Benefit (GMWB) variable annuities over their adult lifetimes. Our contribution is to evaluate demand for these products which provide access to equity investments with money-back guarantees, longevity risk hedging, and partially-refundable premiums, in a realistic world with uncertain labor and capital market income as well as mortality risk. Others have predicted that consumers will only purchase such annuities late in life, but we show that they will optimally purchase

GMWBs prior to retirement, consistent with their recent rapid uptick in sales. Additionally, many individuals optimally adjust their portfolios and consumption streams along the way by taking cash withdrawals from the products. These products can substantially enhance consumption, by up to 10% for those who experience highly unfavorable experiences in the stock market.

HUNT, ANDREW; BLAKE, DAVID. *Modelling longevity bonds: analysing the Swiss Re Kortis bond*. 12–29. A key contribution to the development of the traded market for longevity risk was the issuance of the Kortis bond, the world's first longevity trend bond, by Swiss Re in 2010. We analyse the design of the Kortis bond, develop suitable mortality models to analyse its payoff and discuss the key risk factors for the bond. We also investigate how the design of the Kortis bond can be adapted and extended to further develop the market for longevity risk.

KLEINOW, TORSTEN. *A common age effect model for the mortality of multiple populations*. 147–152. We introduce a model for the mortality rates of multiple populations. To build the proposed model we investigate to what extent a common age effect can be found among the mortality experiences of several countries and use a common principal component analysis to estimate a common age effect in an age-period model for multiple populations. The fit of the proposed model is then compared to age-period models fitted to each country individually, and to the fit of the model proposed by Li and Lee (2005) [N Li, R Lee, Coherent mortality forecasts for a group of populations: an extension of the Lee-Carter method, Demography (2005) 42(3): 575–594]. Although we do not consider stochastic mortality projections in this paper, we argue that the proposed common age effect model can be extended to a stochastic mortality model for multiple populations, which allows to generate mortality scenarios simultaneously for all considered populations. This is particularly relevant when mortality derivatives are used to hedge the longevity risk in an annuity portfolio as this often means that the underlying population for the derivatives is not the same as the population in the annuity portfolio.

LI, HONGYI; DE WAEGENAERE, ANJA; MELENBERG, BERTRAND. *The choice of sample size for mortality forecasting: A Bayesian learning approach*. 153–168. Forecasted mortality rates using mortality models proposed in the recent literature are sensitive to the sample size. In this paper we propose a method based on Bayesian learning to determine model-specific posterior distributions of the sample sizes. In particular, the sample size is included as an extra parameter in the parameter space of the mortality model, and its posterior distribution is obtained based on historical performance for different forecast horizons up to 20 years. Age- and gender-specific posterior distributions of sample sizes are computed. Our method is applicable to a large class of linear mortality models. As illustration, we focus on the first generation of the Lee–Carter model and the Cairns-Blake-Dowd model. Our method is applied to US and Dutch data. For both countries we find highly concentrated posterior distributions of the sample size that are gender- and age-specific. In the out-of-sample forecast analysis, the Bayesian model outperforms the original mortality models with fixed sample sizes in the majority of cases.

LI, JOHNNY SIU-HANG; ZHOU, RUI; HARDY, MARY R. *A step-by-step guide to building two-population stochastic mortality models*. 121–134. Two-population stochastic mortality models play a crucial role in the securitization of longevity risk. In particular, they allow us to quantify the population basis risk when longevity hedges are built from broad-based mortality indexes.

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In this paper, we propose and illustrate a systematic process for constructing a two-population mortality model for a pair of populations. The process encompasses four steps, namely (1) determining the conditions for biological reasonableness, (2) identifying an appropriate base model specification, (3) choosing a suitable time-series process and correlation structure for projecting period and/or cohort effects into the future, and (4) model evaluation. For each of the seven single-population models from Cairns et al. (2009) [A.J.G. Cairns, D. Blake, K. Dowd, G.D. Coughlan, D. Epstein, A. Ong, I. Balevich, A quantitative comparison of stochastic mortality models using data from England and Wales and The United States, North American Actuarial Journal (2009) 13: 1–35], we propose two-population generalizations. We derive criteria required to avoid long-term divergence problems and the likelihood functions for estimating the models. We also explain how the parameter estimates are found, and how the models are systematically simplified to optimize the fit based on the Bayes Information Criterion. Throughout the paper, the results and methodology are illustrated using real data from two pairs of populations.

LIN, YIJIA; MACMINN, RICHARD D; TIAN, RUILIN. *De-risking defined benefit plans.* 52–65. To identify an appropriate pension de-risking method, this paper proposes an optimization model that minimizes the expected total pension cost subject to a conditional value at risk (CVaR) constraint on pension funding level. Using this model, we examine three pension hedging strategies, i.e., longevity hedge, buy-in and buy-out; each strategy is examined with hedging costs that include a risk premium, search and information cost, underfunding cost, and counter-party risk cost. The numerical examples demonstrate that these hedging costs have a significant impact on the hedging decision. The hedge ratio (total pension cost) decreases (increases) with the transaction cost, the counter-party default probability and the underfunding ratio. In addition, the buy-out underperforms the longevity hedge and the buy-in for underfunded plans and the longevity hedge is less sensitive to the default risk than the buy-in.

SHAO, ADAM W; HANEWALD, KATJA; SHERRIS, MICHAEL. *Reverse mortgage pricing and risk analysis allowing for idiosyncratic house price risk and longevity risk.* 76–90. Reverse mortgages provide an alternative source of funding for retirement income and health care costs. The two main risks that reverse mortgage providers face are house price risk and longevity risk. Recent real estate literature has shown that the idiosyncratic component of house price risk is large. We analyse the combined impact of house price risk and longevity risk on the pricing and risk profile of reverse mortgage loans in a stochastic multi-period model. The model incorporates a new hybrid hedonic-repeat-sales pricing model for houses with specific characteristics, as well as a stochastic mortality model for mortality improvements along the cohort direction (the Wills-Sherris model). Our results show that pricing based on an aggregate house price index does not accurately assess the risks underwritten by reverse mortgage lenders, and that failing to take into account cohort trends in mortality improvements substantially underestimates the longevity risk involved in reverse mortgage loans.

TOMAS, JULIEN; PLANCHET, FRÉDÉRIC. *Prospective mortality tables: taking heterogeneity into account.* 169–190. The present article illustrates an approach to construct prospective mortality tables for which the data available are composed by heterogeneous groups observed during different periods. Without explicit consideration of heterogeneity, it is necessary to reduce the period of observation at the intersection of the different populations observation periods. This reduction of the available history can arm the determination of the mortality trend and its extrapolation. We propose a model taking explicitly into account the heterogeneity, so as to

preserve the entire history available for all populations. We use local kernel-weighted log-likelihood techniques to graduate the observed mortality. The extrapolation of the smoothed surface is performed by identifying the mortality components and their importance over time using singular values decomposition. Then time series methods are used to extrapolate the time-varying coefficients. We investigate the divergences in the mortality surfaces generated by a number of previously proposed models on three levels. These concern the proximity between the observations and the model, the regularity of the fit as well as the plausibility and consistency of the mortality trends.

WAN, CHENG; BERTSCHI, LJUDMILA. Swiss coherent mortality model as a basis for developing longevity de-risking solutions for Swiss pension funds: a practical approach. 66–75. Pension funds in Switzerland are exposed to longevity risk possibly to a greater extent than in many other developed economies. The ground for this is a dearth of financial products to combat longevity risk, with a lack of buy-in and very limited variety of buy-out solutions available. The solutions that do exist frequently come at a very high price and many pension funds are in deficit on a buy-out basis. From our point of view creating an approach for evaluating the longevity risk faced by each pension fund and integrating it into dynamic risk budgeting strategies will help Swiss pension funds better understand the mechanism behind different longevity de-risking solutions and decide on the most suitable as well as affordable solution for them. To develop capital market solutions for longevity hedging strategies it is crucial that both hedgers (pension funds) as well as solution providers are able to quantify the longevity risk in the framework of a holistic risk management and to develop an adequate pricing approach. In this publication we present our stochastic coherent mortality model developed for Swiss pension funds based on the reference population of fifteen countries and discuss the robustness of the forecasts relative to the sample period used to fit the model, biological reasonableness of the forecasts and other modelling parameters as well as possible impact on results. The model has taken into account past single population modelling techniques and allows flexible age effect to capture the spread behaviour introduced by the target population. The augmented terms for the spread function are chosen based on their forecast accuracy and a coherent behaviour is expected in the long term. The idea behind is fairly simple and yields a design with both transparency and robustness. The model usage is not limited to Switzerland.

WANG, CHOU-WEN; YANG, SHARON S; HUANG, HONG-CHIH. Modeling multi-country mortality dependence and its application in pricing survivor index swaps: a dynamic copula approach. 30–39. This paper introduces mortality dependence in multi-country mortality modeling using a dynamic copula approach. Specifically, we use time-varying copula models to capture the mortality dependence structure across countries, examining both symmetric and asymmetric dependence structures. In addition, to capture the phenomenon of a heavy tail for the multi-country mortality index, we consider not only the setting of Gaussian innovations but also non-Gaussian innovations under the Lee-Carter framework model. As tests of the goodness of fit of different dynamic copula models, the pattern of mortality dependence, and the distribution of the innovations, we used empirical mortality data from Finland, France, the Netherlands, and Sweden. To understand the effect of mortality dependence on longevity derivatives, we also built a valuation framework for pricing a survivor index swap, then investigated the fair swap rates of a survivor swap numerically. We demonstrate that failing to consider the dynamic copula mortality model and non-Gaussian innovations would lead to serious underestimations of the swap rates and loss reserves.

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AHMADI, SEYED SAEED; GAILLARDETZ, PATRICE. *Modeling mortality and pricing life annuities with Lévy processes.* 337–350. We consider the pricing of annuity-due under stochastic force of mortality. Similarly to Renshaw et al. (1996) and Sithole et al. (2000) [Sithole, T Z; Haberman, S; Verrall, R J (2000), An investigation into parametric models for mortality projections, with applications to immediate annuitants' and life office pensioners' data, Insurance: Mathematics and Economics 27: 285–312], the force of mortality will be defined using an exponential function of Legendre polynomials. We extend the approach of Ballotta and Haberman (2006) [Ballotta, L; Haberman, S (2006), The fair valuation problem of guaranteed annuity options: The stochastic mortality environment case, Insurance: Mathematics and Economics 38: 195–214] by conditionally adding aa-stable Lévy subordinators in the force of mortality. In particular, we focus on the Gamma and Variance-Gamma processes in order to show how Lévy subordinators can capture mortality shocks. Generalized Linear Models is used to estimate coefficients of the explanatory variables and the Lévy process. For this purpose, the coefficients of the process are obtained by maximizing the log-likelihood function. We use the mortality data of males in Japan from 1998–2011 and the U.S. from 1965–2010 in order to compare our results with the model proposed by Renshaw et al. (1996) [Renshaw, A E; Haberman, S; Hatzoupoulos, P (1996), The modelling of recent mortality trends in United Kingdom male assured lives, British Actuarial Journal, 2(2): 449–477]. Some preferences are indicated based on Akaike's information criterion, Bayesian information criterion, likelihood ratio test and Akaike weights to support the proposed model. We then use a cubic smoothing spline method to fit the interest rate curve and illustrate some over (under) estimations in the prices of annuities under the structure suggested by Renshaw et al. (1996) [op. cit.].

ALAI, DANIEL H; ZINOVIY, LANDSMAN; SHERRIS, MICHAEL. *A multivariate Tweedie lifetime model: censoring and truncation.* 203–213. We generalize model calibration for a multivariate Tweedie distribution to allow for censored observations; estimation is based on the method of moments. The multivariate Tweedie distribution we consider incorporates dependence in a pool of lives via a common stochastic component. Pools may be interpreted in various ways, from nation-wide cohorts to employer-based pension annuity portfolios. In general, the common stochastic component is representative of systematic longevity risk, which is not accounted for in standard life tables and actuarial models used for annuity pricing and reserving.

BARMALZAN, GHOBAD; NAJAFABADI, AMIR T PAYANDEH. *On the convex transform and right-spread orders of smallest claim amounts.* 380–384. Suppose $X_1,\ldots,X_n$ is a set of Weibull random variables with shape parameter $a > 0$, scale parameter $i > 0$ for $i = 1,\ldots,n$ and $Ip_1,\ldots,Ip_n$ are independent Bernoulli random variables, independent of the X_i's, with $E(Ip_i) = p_i$, $i = 1,\ldots,$ $n_i = 1,\ldots,n$. Let $Y_i = X_i Ip_i$, for $i = 1,\ldots,n$. In particular, in actuarial science, it corresponds to the claim amount in a portfolio of risks. In this paper, under certain conditions, we discuss stochastic comparison between the smallest claim amounts in the sense of the right-spread order. Moreover, while comparing these two smallest claim amounts, we show that the right-spread order and the increasing convex orders are equivalent. Finally, we obtain the results concerning the convex transform order between the smallest claim amounts and find a lower and upper bound for the coefficient of variation. The results established here extend some well-known results in the literature.

BOUCHER, JEAN-PHILIPPE; COUTURE-PICHÉ, GUILLAUME. *Modeling the number of insureds' cars using queuing theory*. 67–76. In this paper, we propose to model the number of insured cars per household. We use queuing theory to construct a new model that needs 4 different parameters: one that describes the rate of addition of new cars on the insurance contract, a second one that models the rate of removal of insured vehicles, a third parameter that models the cancellation rate of the insurance policy, and finally a parameter that describes the rate of renewal. Statistical inference techniques allow us to estimate each parameter of the model, even in the case where there is censorship of data. We also propose to generalize this new queuing process by adding some explanatory variables into each parameter of the model. This allows us to determine which policyholder's profiles are more likely to add or remove vehicles from their insurance policy, to cancel their contract or to renew annually. The estimated parameters help us to analyze the insurance portfolio in detail because the queuing theory model allows us to compute various kinds of useful statistics for insurers, such as the expected number of cars insured or the customer lifetime value that calculates the discounted future profits of an insured. Using car insurance data, a numerical illustration based on a portfolio from a Canadian insurance company is included to support this discussion.

BUTT, ADAM; KHEMKA, GAURAV. *The effect of objective formulation on retirement decision making*. 385–395. For a retiree who must maintain both investment and longevity risks, we consider the impact on decision making of focusing on an objective relating to the terminal wealth at retirement, instead of a more correct objective relating to a retirement income. Both a shortfall and a utility objective are considered; we argue that shortfall objectives may be inappropriate due to distortion in results with non-monotonically correlated economic factors. The modelling undertaken uses a dynamic programming approach in conjunction with Monte-Carlo simulations of future experience of an individual to make optimal choices. We find that the type of objective targetted can have a significant impact on the optimal choices made, with optimal equity allocations being up to 30% higher and contribution amounts also being significantly higher under a retirement income objective as compared to a terminal wealth objective. The result of these differences can have a significant impact on retirement outcomes.

CHEUNG, KA CHUN; CHONG, WING FUNG; YAM, SHEUNG CHI PHILLIP. *Convex ordering for insurance preferences*. 409–416. In this article, we study two broad classes of convex order related optimal insurance decision problems, in which the objective function or the premium valuation is a general functional of the expectation, Value-at-Risk and Average Value-at-Risk of the loss variables. These two classes of problems include many existing and contemporary optimal insurance problems as interesting examples being prevalent in the literature. To solve these problems, we apply the Karlin-Novikoff-Stoyan-Taylor multiple-crossing conditions, which is a useful sufficient criterion in the theory of convex ordering, to replace an arbitrary insurance indemnity by a more favorable one in convex order sense. The convex ordering established provides a unifying approach to solve the special cases of the problem classes. We show that the optimal indemnities for these problems in general take the double layer form.

CHEUNG, KA CHUN; CHONG, WING FUNG; YAM, SHEUNG CHI PHILLIP. *The optimal insurance under disappointment theories*. 77–90. In his celebrated work, Arrow (1974) [Arrow, K J (1974), Optimal insurance and generalized deductibles, Scandinavian Actuarial Journal 1: 1–42] was first to discover the optimality of deductible insurance under Expected Utility Theory; recently, Kaluszka and Okolewski (2008) [Kaluszka, M; Okolewski, A (2008), An extension of Arrow's result on optimal reinsurance contract, Journal of Risk and Insurance

75: 275–288] extended Arrow's result by generalizing the premium constraint as a convex combination of the expected value and the supremum of an insurance indemnity, with single layer insurance as the optimal solution. Nevertheless, the Expected Utility Theory has constantly been criticized for its failure in capturing the actual human decision making, and its shortcoming motivates the recent development of behavioral economics and finance, such as the Disappointment Theory; this theory was first developed by (1) Bell (1985) [Bell, D E (1985), Disappointment in decision making under uncertainty, Operational Research 33: 1–27], and Loomes and Sugden (1986) [Loomes, G; Sugden, R (1986), Disappointment and dynamic consistency in choice under uncertainty, Review of Economic Studies 53: 271–282], that can successfully explain the Allais Paradox. Their theory was later enhanced to the (2) Disappointment Aversion Theory by Gul (1991) [Gul, F (1991), A theory of disappointment aversion, Econometrica 59: 667–686], and then (3) Disappointment Theory without prior expectation by Cillo and Delquié (2006) [Cillo, A; Delquié, P (2006), Disappointment without prior expectation: a unifying perspective on decision under risk, Journal of Risk and Uncertainty 33: 197–215]. In our present paper, we extend the problem studied by Kaluszka and Okolewski (2008) [op. cit.] over the three mentioned disappointment models, while the solutions are still absent in the literature. We also conclude with the uniform optimality of the class of single layer indemnities in all these models.

COSSETTE, HÉLÈNE; MARCEAU, ÉTIENNE; PERREAULT, SAMUEL. *On two families of bivariate distributions with exponential marginals: aggregation and capital allocation.* 214–224. In this paper, we consider two main families of bivariate distributions with exponential marginals for a couple of random variables (X1,X2). More specifically, we derive closed-form expressions for the distribution of the sum $S = X1 + X2S$, the TVaR of SS and the contributions of each risk under the TVaR-based allocation rule. The first family considered is a subset of the class of bivariate combinations of exponentials, more precisely, bivariate combinations of exponentials with exponential marginals. We show that several well-known bivariate exponential distributions are special cases of this family. The second family we investigate is a subset of the class of bivariate mixed Erlang distributions, namely bivariate mixed Erlang distributions with exponential marginals. For this second class of distributions, we propose a method based on the compound geometric representation of the exponential distribution to construct bivariate mixed Erlang distributions with exponential marginals. Notably, we show that this method not only leads to Moran-Downton's bivariate exponential distribution, but also to a generalization of this bivariate distribution. Moreover, we also propose a method to construct bivariate mixed Erlang distributions with exponential marginals from any absolutely continuous bivariate distributions with exponential marginals. Inspired from Lee and Lin (2012) [Lee, S C K; Lin, X S (2012), Modeling dependent risks with multivariate Erlang mixtures, ASTIN Bulletin 42(1): 153–180], we show that the resulting bivariate distribution approximates the initial bivariate distribution and we highlight the advantages of such an approximation.

DAI, TIAN-SHYR; YANG, SHARON S; LIU, LIANG-CHIH. Pricing guaranteed minimum/lifetime withdrawal benefits with various provisions under investment, interest rate and mortality risks. 364–379. Many variable annuity products associated with guaranteed minimum withdrawal benefit (GMWB) or its lifelong version, a guaranteed lifelong withdrawal benefit (GLWB), have enjoyed great market success in the United States and Asia. The interaction impacts among complex policy provisions and the randomness of the account value of the policy, the prevailing interest rate, as well as the mortality rate may significantly influence the evaluations of GMWBs/GMLBs, especially when the guaranteed payments are made over a long, or even a lifelong, horizon. To deal with aforementioned risk factors and policy provisions, this paper

proposes a novel three-dimensional (3D) tree that can analyze how different policy provisions influence the evaluation of GMWB/GLWBs under investment interest rate, and mortality risks simultaneously. The orthogonalization method is used to convert correlated dynamics of the account value of the policy and the short-term interest rate into two independent processes that can be easily simulated by our 3D tree. Besides, the structure of our 3D tree is sophisticatedly designed to avoid the unstable (oscillating) pricing results phenomenon that has characterized many numerical pricing methods. Rigorous numerical experiments are given to analyze the interaction effects among policy provisions and the aforementioned risk factors on the evaluation of GMWBs/GLWBs.

DENUIT, MICHEL; TRUFIN, JULIEN. *Model points and Tail-VaR in life insurance.* 268–272. Life insurance models are becoming more and more sophisticated under Solvency 2 regulation. European insurance companies are required to base their cash-flow projection on a policy-by-policy approach on the one hand, and to demonstrate the compliance of their internal model by carrying out additional testing on the other hand (see EIOPA, 2010) [EIOPA. QIS5 Technical Specification. European commission]. In particular, one of the validation tools recommended by the regulator is sensitivity testing, which consists in estimating the impact on the model outcomes of various changes in the underlying risk factors. Next to the baseline runs, insurers are then invited to conduct sensitivity analyses. Usually, all those studies need to be performed within tight deadlines. However, the use of Monte-Carlo simulations based on a policy-by-policy approach often leads to large running times (up to several days for the entire portfolio with the currently available computing power). Saving time when running the models thus appears to be an issue of major importance in life insurance.

DONNELLY, CATHERINE; GERRARD, RUSSELL; GUILLÉN, MONTSERRAT; NIELSEN, JENS PERCH. *Less is more: increasing retirement gains by using an upside terminal wealth constraint.* 259–267. We solve a portfolio selection problem of an investor with a deterministic savings plan who aims to have a target wealth value at retirement. The investor is an expected power utility-maximizer. The target wealth value is the maximum wealth that the investor can have at retirement. By constraining the investor to have no more than the target wealth at retirement, we find that the lower quantiles of the terminal wealth distribution increase, so the risk of poor financial outcomes is reduced. The drawback of the optimal strategy is that the possibility of gains above the target wealth is eliminated.

GERBER, HANS U; SHIU, ELIAS S W; YANG, HAILIANG. *Geometric stopping of a random walk and its applications to valuing equity-linked death benefits.* 313–325. We study discrete-time models in which death benefits can depend on a stock price index, the logarithm of which is modeled as a random walk. Examples of such benefit payments include put and call options, barrier options, and lookback options. Because the distribution of the curtate-future-lifetime can be approximated by a linear combination of geometric distributions, it suffices to consider curtate-future-lifetimes with a geometric distribution. In binomial and trinomial tree models, closed-form expressions for the expectations of the discounted benefit payment are obtained for a series of options. They are based on results concerning geometric stopping of a random walk, in particular also on a version of the Wiener-Hopf factorization.

GOMES-GONÇALVES, ERIKA; GZYL, HENRYK; MAYORAL, SILVIA. *Maxentropic approach to decompound aggregate risk losses.* 326–336. A risk manager may be faced with the following problem: she/he has obtained loss data collected during a year, but the data only contains the total

number of events and the total loss for that year. She/he suspects that there are different sources of risk, each occurring with a different frequency, and wants to identify the frequency with which each type of event occurs and if possible, the individual losses at each risk event. The purpose of this methodological note is to examine a combination of disentangling and decompounding procedures, to get as close as possible to that goal. The disentangling procedure is actually a two step process: First, a preliminary analysis is carried out to determine the number of risks groups present. Once that is decided, the underlying model for the frequency of each type of risk is worked out. After that we use the maxentropic techniques in the decompounding stage to determine the distribution of individual losses that aggregated yield the observed total loss.

HÄRDLE, WOLFGANG KARL; LÓPEZ CABRERA, BRENDA; TENG, HUEI-WEN. *State price densities implied from weather derivatives.* 106–125. A State Price Density (SPD) is the density function of a risk neutral equivalent martingale measure for option pricing, and is indispensable for exotic option pricing and portfolio risk management. Many approaches have been proposed in the last two decades to calibrate a SPD using financial options from the bond and equity markets. Among these, non and semiparametric methods were preferred because they can avoid model mis-specification of the underlying. However, these methods usually require a large data set to achieve desired convergence properties. One faces the problem in estimation by e.g., kernel techniques that there are not enough observations locally available. For this situation, we employ a Bayesian quadrature method because it allows us to incorporate prior assumptions on the model parameters and hence avoids problems with data sparsity. It is able to compute the SPD of both call and put options simultaneously, and is particularly robust when the market faces the data sparsity issue. As illustration, we calibrate the SPD for weather derivatives, a classical example of incomplete markets with financial contracts payoffs linked to non-tradable assets, namely, weather indices. Finally, we study related weather derivatives data and the dynamics of the implied SPDs.

HATZOPOULOS, PETER; HABERMAN, STEVEN. *Modeling trends in cohort survival probabilities.* 162–179. A new dynamic parametric model is proposed for analyzing the cohort survival function. A one-factor parameterized polynomial in age effects, complementary log–log link and multinomial cohort responses are utilized, within the generalized linear models (GLM) framework. Sparse Principal component analysis (SPCA) is then applied to cohort dependent parameter estimates and provides (marginal) estimates for a two-factor structure. Modeling the two-factor residuals in a similar way, in age–time effects, provides estimates for the three-factor age-cohort-period model. An application is presented for Sweden, Norway, England & Wales and Denmark mortality experience.

HUANG, JINLONG; QIU, CHUNJUAN; WU, XIANYI; ZHOU, XIAN. *An individual loss reserving model with independent reporting and settlement.* 232–245. The main purpose of this paper is to assess and demonstrate the advantage of claims reserving models based on individual data in forecasting future liabilities over traditional models on aggregate data both theoretically and numerically. The available information consists of the reporting delays, settlement delays and claim payments. The model settings include Poisson distributed frequency of claims produced by each policy, claims payable at the settlement time, and the amount of payment depending only on its settlement delay. While such settings are applicable to certain but not all practical cases, the principal purpose of the paper is to examine the efficiency of individual data against aggregate data. We refer to loss reserving as to estimate the projections of the outstanding liabilities on observed information. The efficiency of the individual loss reserving against classical aggregate loss reservings, namely Chain-Ladder (C-L) and Bornhuetter-Ferguson (B-F), is assessed by comparing

the asymptotic variances of the errors in estimating the conditional expectation (projection) of the outstanding liability between individual, C-L and B-F reservings. The research shows a significant increase in the accuracy of loss reserving by using individual data compared with aggregate data.

HUNT, ANDREW; VILLEGAS, ANDRÉS M. *Robustness and convergence in the Lee-Carter model with cohort effects*. 186–202. Interest in cohort effects in mortality data has increased dramatically in recent years, with much of the research focused on extensions of the Lee-Carter model incorporating cohort parameters. However, some studies find that these models are not robust to changes in the data or fitting algorithm, which limits their suitability for many purposes. It has been suggested that these robustness problems may be the result of an unresolved identifiability issue. In this paper, after investigating systemically the robustness of cohort extensions of the Lee-Carter model and the convergence of the algorithms used to fit it to data, we demonstrate the existence of such an identifiability issue and propose an additional approximate identifiability constraint which solves many of the problems found.

IKEFUJI, MASAKO; LAEVEN, ROGER J A; MAGNUS, JAN R; MURIS, CHRIS. *Expected utility and catastrophic consumption risk*. 306–312. An expected utility based cost-benefit analysis is, in general, fragile to distributional assumptions. We derive necessary and sufficient conditions on the utility function of consumption in the expected utility model to avoid this. The conditions ensure that expected (marginal) utility of consumption and the expected intertemporal marginal rate of substitution that trades off consumption and self-insurance remain finite, also under heavy-tailed distributional assumptions. Our results are relevant to various fields encountering catastrophic consumption risk in cost-benefit analysis.

IVANOVS, JEVGENIJS; BOXMA, ONNO J. *A bivariate risk model with mutual deficit coverage*. 126–134. We consider a bivariate Cramér-Lundberg-type risk reserve process with the special feature that each insurance company agrees to cover the deficit of the other. It is assumed that the capital transfers between the companies are instantaneous and incur a certain proportional cost, and that ruin occurs when neither company can cover the deficit of the other. We study the survival probability as a function of initial capitals and express its bivariate transform through two univariate boundary transforms, where one of the initial capitals is fixed at 0. We identify these boundary transforms in the case when claims arriving at each company form two independent processes. The expressions are in terms of Wiener-Hopf factors associated to two auxiliary compound Poisson processes. The case of non-mutual agreement is also considered. The proposed model shares some features of a contingent surplus note instrument and may be of interest in the context of crisis management.

JANG, JI-WOOK; RAMLI, SITI NORAFIDAH MOHD. *Jump diffusion transition intensities in life insurance and disability annuity*. 440–451. We study the effects of jump diffusion transition intensities on a life insurance and disability annuity. To do so, we use a multi-states Markov chain with multiple decrement. Assuming independent statewise intensities, we evaluate the prospective reserve for this scheme where the insured life is in Active or Disabled state at inception, respectively. We also examine the components of the prospective reserves by changing the relevant parameters of the transition intensities, which are the jump size, the average frequency of jumps as well as the diffusion parameters, assuming deterministic rate of interest. The computation of the reserve sensitivity with their figures are provided.

JIANG, TAO; WANG, YUEBAO; CHEN, YANG; XU, HUI. *Uniform asymptotic estimate for finite-time ruin probabilities of a time-dependent bidimensional renewal model*. 45–53. This paper

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studies a bidimensional renewal risk model with constant force of interest and subexponentially distributed claim size vector. Some uniform asymptotic estimates for finite-time ruin probabilities are established when the claim size vector and its inter-arrival time are subject to certain general dependence structure.

JIN, ZHUO; YANG, HAILIANG; YIN, G. *Optimal debt ratio and dividend payment strategies with reinsurance*. 351–363. This paper derives the optimal debt ratio and dividend payment strategies for an insurance company. Taking into account the impact of reinsurance policies and claims from the credit derivatives, the surplus process is stochastic that is jointly determined by the reinsurance strategies, debt levels, and unanticipated shocks. The objective is to maximize the total expected discounted utility of dividend payment until financial ruin. Using dynamic programming principle, the value function is the solution of a second-order nonlinear Hamilton-Jacobi-Bellman equation. The subsolution-supersolution method is used to verify the existence of classical solutions of the Hamilton-Jacobi-Bellman equation. The explicit solution of the value function is derived and the corresponding optimal debt ratio and dividend payment strategies are obtained in some special cases. An example is provided to illustrate the methodologies and some interesting economic insights.

LI, DANPING; RONG, XIMIN; ZHAO, HUI. *Time-consistent reinsurance-investment strategy for a mean-variance insurer under stochastic interest rate model and inflation risk*. 28–44. In this paper, we consider the time-consistent reinsurance–investment strategy under the mean–variance criterion for an insurer whose surplus process is described by a Brownian motion with drift. The insurer can transfer part of the risk to a reinsurer via proportional reinsurance or acquire new business. Moreover, stochastic interest rate and inflation risks are taken into account. To reduce the two kinds of risks, not only a risk-free asset and a risky asset, but also a zero-coupon bond and Treasury Inflation Protected Securities (TIPS) are available to invest in for the insurer. Applying stochastic control theory, we provide and prove a verification theorem and establish the corresponding extended Hamilton–Jacobi–Bellman (HJB) equation. By solving the extended HJB equation, we derive the time-consistent reinsurance–investment strategy as well as the corresponding value function for the mean–variance problem, explicitly. Furthermore, we formulate a precommitment mean–variance problem and obtain the corresponding time-inconsistent strategy to compare with the time-consistent strategy. Finally, numerical simulations are presented to illustrate the effects of model parameters on the time-consistent strategy.

LIANG, ZONGXIA; MA, MING. *Optimal dynamic asset allocation of pension fund in mortality and salary risks framework*. 151–161. In this paper, we consider the optimal dynamic asset allocation of pension fund with mortality risk and salary risk. The managers of the pension fund try to find the optimal investment policy (optimal asset allocation) to maximize the expected utility of terminal wealth. The market is a combination of financial market and insurance market. The financial market consists of three assets: cashes with stochastic interest rate, stocks and rolling bonds, while the insurance market consists of mortality risk and salary risk. These two non-hedging risks cause incompleteness of the market. By martingale method and dynamic programming principle we first derive the approximate optimal investment policy to overcome the difficulty, then investigate the efficiency of the approximation. Finally, we solve an optimal assets liabilities management(ALM) problem with mortality risk and salary risk under CRRA utility, and reveal the influence of these two risks on the optimal investment policy by numerical illustration.

LIU, AIAI; HOU, YANXI; PENG, LIANG. *Interval estimation for a measure of tail dependence*. 294–305. Systemic risk concerns extreme co-movement of several financial variables, which

involves characterizing tail dependence. The coefficient of tail dependence was proposed by Ledford and Tawn (1996) [Ledford, A W; Tawn, J (1996), Statistics for near independence in multivariate extreme values, Biometrika, 83: 169–187] and Ledford and Tawn (1997) [A.W. Ledford, J. Tawn (1997), Modelling dependence within joint tail regions, Journal of the Royal Statistical Society: Series B: Statistical Methodology 59: 475–499] to distinguish asymptotic independence and asymptotic dependence. Recently a new measure based on the conditional Kendall's tau was proposed by Asimit et al. (2015) [Asimit, A; Gerrard, R; Hou, Y; Peng, L (2015), Tail dependence measure for modeling financial extreme co-movements, Journal of Econometrics (2015) to appear] to measure the tail dependence and to distinguish asymptotic independence and asymptotic dependence. For effectively constructing a confidence interval for this new measure, this paper proposes a smooth jackknife empirical likelihood method, which does not need to estimate any additional quantities such as asymptotic variance. A simulation study shows that the proposed method has a good finite sample performance.

LIU, YANXIN; LI, JOHNNY SIU-HANG. *The age pattern of transitory mortality jumps and its impact on the pricing of catastrophic mortality bonds.* 135–150. To value catastrophic mortality bonds, a number of stochastic mortality models with transitory jump effects have been proposed. Rather than modeling the age pattern of jump effects explicitly, most of the existing models assume that the distributions of jump effects and general mortality improvements across ages are identical. Nevertheless, this assumption does not seem to be in line with what we observe from historical data. In this paper, we address this problem by introducing a Lee-Carter variant that captures the age pattern of mortality jumps by a distinct collection of parameters. The model variant is then further generalized to permit the age pattern of jump effects to vary randomly. We illustrate the two proposed models with mortality data from the United States and English and Welsh populations, and use them to value hypothetical mortality bonds with similar specifications to the Atlas IX Capital Class B note that was launched in 2013. It is found that the features we consider have a significant impact on the estimated prices.

LIU, YING; LI, XIAOZHONG; LU, YINLI. *The bounds of premium and optimality of stop loss insurance under uncertain random environments.* 273–278. The potential loss of insured can be affected by many nondeterministic factors, in which uncertainty always coexists with randomness. Therefore, uncertain random variables are used to describe this phenomenon of simultaneous appearance of both uncertainty and randomness in potential loss. Based on that, the upper and lower bounds of premium with uncertain random loss are given, respectively. Moreover, a mathematical model of uncertain random optimal insurance problem is established and the stop loss insurance is proved to be the optimal insurance policy and the equation for calculating the optimal deductible is arrived. Some numerical examples are also given for illustration.

MAO, TIANTIAN; YANG, FAN. *Risk concentration based on Expectiles for extreme risks under FGM copula.* 429–439. Risk concentration is used as a measurement of diversification benefits in the context of risk aggregation. Expectiles, which are known to possess many good properties, have attracted increasing interest in recent years. In this paper, we aim to study the asymptotic properties of risk concentration based on Expectiles. Firstly, we extend the results on the second-order asymptotics of Expectiles in Mao et al. (2015) [T. Mao, T; Ng, K; Hu, T (2015), Asymptotics of generalized quantiles and Expectiles for extreme risks, Probability in the Engineering and Informational Sciences 29(3): 309–327]. Secondly, we investigate the second-order asymptotics of tail probabilities and then apply them to risk concentrations based on Expectiles as well as on VaR.

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MILEVSKY, MOSHE ARYE; SALISBURY, THOMAS S. *Optimal retirement income tontines.* 91–105. Tontines were once a popular type of mortality-linked investment pool. They promised enormous rewards to the last survivors at the expense of those died early. While this design appealed to the gambling instinct, it is a suboptimal way to generate retirement income. Indeed, actuarially fair life annuities making constant payments – where the insurance company is exposed to longevity risk – induce greater lifetime utility. However, tontines do not have to be structured the historical way, i.e. with a constant cash flow shared amongst a shrinking group of survivors. Moreover, insurance companies do not sell actuarially-fair life annuities, in part due to aggregate longevity risk. We derive the tontine structure that maximizes lifetime utility. Technically speaking we solve the Euler–Lagrange equation and examine its sensitivity to (i) the size of the tontine pool n, and (ii) individual longevity risk aversion . We examine how the optimal tontine varies with and nn, and prove some qualitative theorems about the optimal payout. Interestingly, Lorenzo de Tonti's original structure is optimal in the limit as longevity risk aversion 8. We define the natural tontine as the function for which the payout declines in exact proportion to the survival probabilities, which we show is near-optimal for all and n. We conclude by comparing the utility of optimal tontines to the utility of loaded life annuities under reasonable demographic and economic conditions and find that the life annuity's advantage over the optimal tontine is minimal. In sum, this paper's contribution is to (i) rekindle a discussion about a retirement income product that has been long neglected, and (ii) leverage economic theory as well as tools from mathematical finance to design the next generation of tontine annuities.

PITSELIS, GEORGIOS; GRIGORIADOU, VASILIKI; BADOUNAS, IOANNIS. *Robust loss reserving in a log-linear model.* 14–27. It is well known that the presence of outlier events can overestimate or underestimate the overall reserve when using the chain-ladder method. The lack of robustness of loss reserving estimators leads to the development of this paper. The appearance of outlier events (including large claims – catastrophic events) can offset the result of the ordinary chain ladder technique and perturb the reserving estimation. Our proposal is to apply robust statistical procedures to the loss reserving estimation, which are insensitive to the occurrence of outlier events in the data. This paper considers robust log-linear and ANOVA models to the analysis of loss reserving by using different type of robust estimators, such as LAD-estimators, M-estimators, LMS-estimators, LTS-estimators, MM-estimators (with initial S-estimate) and Adaptive-estimators. Comparisons of these estimators are also presented, with application of a well known data set.

SCOTT, ALEXANDRE; METZLER, ADAM. *A general importance sampling algorithm for estimating portfolio loss probabilities in linear factor models.* 279–293. This paper develops a novel importance sampling algorithm for estimating the probability of large portfolio losses in the conditional independence framework. We apply exponential tilts to (i) the distribution of the natural sufficient statistics of the systematic risk factors and (ii) conditional default probabilities, given the simulated values of the systematic risk factors, and select parameter values by minimizing the Kullback–Leibler divergence of the resulting parametric family from the ideal (zero-variance) importance density. Optimal parameter values are shown to satisfy intuitive moment-matching conditions, and the asymptotic behaviour of large portfolios is used to approximate the requisite moments. In a sense we generalize the algorithm of Glasserman and Li (2005) [Glasserman, P; Li, J (2005), Importance sampling for portfolio credit risk, Management Science 51(11): 1643–1656] so that it can be applied in a wider variety of models. We show how to implement our algorithm in the tt copula model and compare its performance there to the algorithm developed by Chan and Kroese (2010) [Chan, J C C; Kroese, D P (2010), Efficient estimation of large portfolio loss

probabilities in t-copula models, *European Journal of Operational Research* 205(2): 361–367]. We find that our algorithm requires substantially less computational time (especially for large portfolios) but is slightly less accurate. Our algorithm can also be used to estimate more general risk measures, such as conditional tail expectations, whereas Chan and Kroese (2010) [op. cit.] is specifically designed to estimate loss probabilities.

SHI, PENG; FENG, TIANJUN; IVANTSOVA, ANASTASIA. *Dependent frequency-severity modeling of insurance claims.* 417–428. Standard ratemaking techniques in non-life insurance assume independence between the number and size of claims. Relaxing the independence assumption, this article explores methods that allow for the correlation among frequency and severity components for micro-level insurance data. To introduce granular dependence, we rely on a hurdle modeling framework where the hurdle component concerns the occurrence of claims and the conditional component looks into the number and size of claims given occurrence. We propose two strategies to correlate the number of claims and the average claim size in the conditional component. The first is based on conditional probability decomposition and treats the number of claims as a covariate in the regression model for the average claim size, the second employed a mixed copula approach to formulate the joint distribution of the number and size of claims. We perform a simulation study to evaluate the performance of the two approaches and then demonstrate their application using a U.S. auto insurance dataset. The hold-out sample validation shows that the proposed model is superior to the industry benchmarks including the Tweedie and the two-part generalized linear models.

STEINORTH, PETRA; MITCHELL, OLIVIA S. *Valuing variable annuities with guaranteed minimum lifetime withdrawal benefits.* 246–258. Variable annuities with guaranteed minimum lifetime withdrawal benefits (VA/GLWB) offer retirees longevity protection, exposure to equity markets, and access to flexible withdrawals in emergencies. We model how risk-averse retirees optimally withdraw from the products, balancing returns and the embedded longevity protection. Assuming reasonable individual preferences, the resulting cash flow generates a Money's Worth Ratio of around 0.9 for our stylized VA/GLWB in the post-crisis product, considerably lower than what was offered prior to 2008. Sensitivity analyses with respect to portfolio choice, mortality, fees, and guaranteed withdrawal rates show that MWRs range from 0.80 to 1.0, with the portfolio choice making the biggest difference. For most parameter choices, the utility value of the VA/GLWB exceeds that of a similar mutual fund, but it is less than for a fixed annuity. Interestingly, VA/GLWB withdrawals in early retirement can optimally exceed contract maximum withdrawals, despite the fact that this reduces future withdrawal guarantees.

WANG, HONGXIA; WANG, JIANLI; LI, JINGYUAN; XIA, XINPING. *Precautionary paying for stochastic improvements under background risks.* 180–185. In a two-dimensional framework, we propose a general two-period decision model which extends the temporal precautionary saving and effort model. We relate the role of cross-prudence to the impact of background risks on paying for stochastic improvements of the future risk. We find that the effect of background risks introduced in the first period is consistent to signing cross derivatives of bivariate utility functions, which is independent of the type of stochastic improvements brought by additional paying; however, when the background risk occurs in the second period, that is not the case.

WU, HUILING; ZENG, YAN. Equilibrium investment strategy for defined-contribution pension schemes with generalized mean-variance criterion and mortality risk. 396–408. This paper studies a generalized multi-period mean-variance portfolio selection problem within the game theoretic

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framework for a defined-contribution pension scheme member. The member is assumed to have a stochastic salary flow and a stochastic mortality rate, and is allowed to invest in a financial market with one risk-free asset and one risky asset. The explicit expressions for the equilibrium investment strategy and equilibrium value function are obtained by backward induction. In addition, some sensitivity analysis and numerical illustrations are provided to show the effects of mortality risk on our results.

WU, YANG-CHE. *Reexamining the feasibility of diversification and transfer instruments on smoothing catastrophe risk*. 54–66. The present study discusses the effects of diversification and transfer of risk by global insurers on smoothing the peak of catastrophic claims. Empirical experiments indicate that the occurrence frequency of natural catastrophes (NatCat) has a serially dependent trend and that the Cox-Ingersoll-Ross square-root model for global insured losses is best fit than any other static distributions. The results are used to develop a NatCat risk insurance model that sets up a NatCat premium formula, uses the serially dependent dynamics of insured loss and establishes the cash flow of all involved parties while considering corporate income tax and no additional risk premium. The simulation results based on this model shows that fluctuation reserves, catastrophe bonds and catastrophe funds with payback schemes are feasible options for smoothing risk because they can benefit all long-term involved parties, including insurance company shareholders, the insured, bondholders, the fund and the government (i.e. taxpayers).

YOU, YINPING; LI, XIAOHU. *Functional characterizations of bivariate weak SAI [stochastic arrangement increasing] with an application*. 225–231. This paper presents functional characterizations of the bivariate right tail weakly stochastic arrangement increasing (RWSAI) and left tail weakly stochastic arrangement increasing (LWSAI) (Cai and Wei, 2014 [J. Cai, J; Wei, W (2014), Some new notions of dependence with applications in optimal allocation problems, Insurance Mathematics & Economics 55: 200–209] and Cai and Wei, 2015 [Cai, J; Wei, W (2015), Notions of multivariate dependence and their applications in optimal portfolio selections with dependent risks, Journal of Multivariate Analysis 138: 156–169]). The present theories are also applied to ordering generalized weighted sum of dependent random variables. Some recent related results in Mao et al. (2013) [Mao, T; Pan, X; Hu, T (2013), On ordering between weighted sums of random variables, Probability in the Engineering and Informational Sciences 27: 85–97] are either improved or extended.

YUEN, KAM CHUEN; LIANG, ZHIBIN; ZHOU, MING. *Optimal proportional reinsurance with common shock dependence*. 1–13. In this paper, we consider the optimal proportional reinsurance strategy in a risk model with multiple dependent classes of insurance business, which extends the work of Liang and Yuen (2014) [Liang, Z and Yuen, K C (2014). Optimal dynamic reinsurance with dependent risks: variance premium principle, Scandinavian Actuarial Journal (2014)] to the case with the reinsurance premium calculated under the expected value principle and to the model with two or more classes of dependent risks. Under the criterion of maximizing the expected exponential utility, closed-form expressions for the optimal strategies and value function are derived not only for the compound Poisson risk model but also for the diffusion approximation risk model. In particular, we find that the optimal reinsurance strategies under the expected value premium principle are very different from those under the variance premium principle in the diffusion risk model. The former depends not only on the safety loading, time and interest rate, but also on the claim size distributions and the counting processes, while the latter depends only on the safety loading, time and interest rate. Finally, numerical examples are presented to show the impact of model parameters on the optimal strategies.

ASIMIT, ALEXANDRU V; CHI, YICHUN; HU, JUNLEI. *Optimal non-life reinsurance under Solvency II.* 227–237. The optimal reinsurance contract is investigated from the perspective of an insurer who would like to minimise its risk exposure under Solvency II. Under this regulatory framework, the insurer is exposed to the retained risk, reinsurance premium and change in the risk margin requirement as a result of reinsurance. Depending on how the risk margin corresponding to the reserve risk is calculated, two optimal reinsurance problems are formulated. We show that the optimal reinsurance policy can be in the form of two layers. Further, numerical examples illustrate that the optimal two-layer reinsurance contracts are only slightly different under these two methodologies.

CHEN, XINFU; LANDRIAULT, DAVID; LI, BIN; LI, DONGCHEN. *On minimizing drawdown risks of lifetime investments.* 46–54. Drawdown measures the decline of portfolio value from its historic high-water mark. In this paper, we study a lifetime investment problem aiming at minimizing the risk of drawdown occurrences. Under the Black-Scholes framework, we examine two financial market models: a market with two risky assets, and a market with a risk-free asset and a risky asset. Closed-form optimal trading strategies are derived under both models by utilizing a decomposition technique on the associated Hamilton-Jacobi-Bellman (HJB) equation. We show that it is optimal to minimize the portfolio variance when the fund value is at its historic high-water mark. Moreover, when the fund value drops, the proportion of wealth invested in the asset with a higher instantaneous rate of return should be increased. We find that the instantaneous return rate of the minimum lifetime drawdown probability (MLDP) portfolio is never less than the return rate of the minimum variance (MV) portfolio. This supports the practical use of drawdown-based performance measures in which the role of volatility is replaced by drawdown.

CHOO, WEIHAO; DE JONG, PIET. *The tradeoff insurance premium as a two-sided generalisation of the distortion premium.* 238–246. This paper introduces and analyzes the "tradeoff premium", generalising the loss aversion reserve, distortion premium, spectral risk, and their duals. The tradeoff premium is a weighted average loss where weights increase as loss outcomes deviate from a subjective "loss appetite", rather than from zero. The U-shaped weights replicate subjective probability adjustment in cumulative prospect theory, and minimise pricing error in a competitive market where overpricing and underpricing are both undesired.

CONSIGLIO, ANDREA; TUMMINELLO, MICHELE; ZENIOS, STAVROS A. *Designing and pricing guarantee options in defined contribution pension plans.* 267–279. The shift from defined benefit (DB) to defined contribution (DC) is pervasive among pension funds, due to demographic changes and macroeconomic pressures. In DB all risks are borne by the provider, while in plain vanilla DC all risks are borne by the beneficiary. However, for DC to provide income security some kind of guarantee is required. A minimum guarantee clause can be modeled as a put option written on some underlying reference portfolio and we develop a discrete model that selects the reference portfolio to minimize the cost of a guarantee. While the relation DB–DC is typically viewed as a binary one, the model shows how to price a wide range of guarantees creating a continuum between DB and DC. Integrating guarantee pricing with asset allocation decision is useful to both pension fund managers and regulators. The former are given a yardstick to assess if a given asset portfolio is fit-for-purpose; the latter can assess differences of specific reference funds with respect to the optimal one, signaling possible cases of moral hazard. We develop the model and report numerical results to illustrate its uses.

DASSIOS, ANGELOS; JANG, JIWOOK; ZHAO, HONGBIAO. *A risk model with renewal shot-noise Cox process.* 55–65. In this paper we generalise the risk models beyond the ordinary framework of affine processes or Markov processes and study a risk process where the claim arrivals are driven by a Cox process with renewal shot-noise intensity. The upper bounds of the finite-horizon and infinite-horizon ruin probabilities are investigated and an efficient and exact Monte Carlo simulation algorithm for this new process is developed. A more efficient estimation method for the infinite-horizon ruin probability based on importance sampling via a suitable change of probability measure is also provided; illustrative numerical examples are also provided.

EISENBERG, JULIA. *Optimal dividends under a stochastic interest rate.* 259–266. We consider an insurance entity endowed with an initial capital and an income, modelled as a Brownian motion with drift. The discounting factor is modelled as a stochastic process: at first as a geometric Brownian motion, then as an exponential function of an integrated Ornstein-Uhlenbeck process. It is assumed that the insurance company seeks to maximize the cumulated value of expected discounted dividends up to the ruin time. We find an explicit expression for the value function and for the optimal strategy in the first but not in the second case, where one has to switch to the viscosity ansatz.

EKHEDEN, ERLAND; HÖSSJER, OLA. *Multivariate time series modeling, estimation and prediction of mortalities.* 156–171. We introduce a mixed regression model for mortality data which can be decomposed into a deterministic trend component explained by the covariates age and calendar year, a multivariate Gaussian time series part not explained by the covariates, and binomial risk. Data can be analyzed by means of a simple logistic regression model when the multivariate Gaussian time series component is absent and there is no overdispersion. In this paper we rather allow for overdispersion and the mixed regression model is fitted to mortality data from the United States and Sweden, with the aim to provide prediction and intervals for future mortality and annuity premium, as well as smoothing historical data, using the best linear unbiased predictor. We find that the form of the Gaussian time series has a large impact on the width of the prediction intervals, and it poses some new questions on proper model selection.

GUAMBE, CALISTO; KUFAKUNESU, RODWELL. *A note on optimal investment-consumption-insurance in a Lévy market.* 30–36. In Shen and Wei (2014) [Y. Shen, J. Wei (2014), Optimal investment-consumption-insurance with random parameters, Scandinavian Actuarial Journal (2014) http://dx.doi.org/10.1080/03461238.2014.900518] an optimal investment, consumption and life insurance purchase problem for a wage earner with Brownian information has been investigated. This paper discusses the same problem but extend their results to a geometric Itô–Lévy jump process. Our modelling framework is very general as it allows random parameters which are unbounded and involves some jumps. It also covers parameters which are both Markovian and non-Markovian functionals. Unlike in Shen and Wei (2014) who considered a diffusion framework, ours solves the problem using a novel approach, which combines the Hamilton-Jacobi-Bellman (HJB) and a backward stochastic differential equation (BSDE) in a Lévy market setup. We illustrate our results by two examples.

HAO, XUEMIAO; LI, XUAN. *Pricing credit default swaps with a random recovery rate by a double inverse Fourier transform.* 103–110. We evaluate the par spread for a single-name credit default swap with a random recovery rate. It is carried out under the framework of a structural default model in which the asset-value process is of infinite activity but finite variation. The recovery rate is assumed to depend on the undershoot of the asset value below the default threshold when default occurs. The key part is to evaluate a generalized expected discounted penalty function,

which is a special case of the so-called Gerber-Shiu function in actuarial ruin theory. We first obtain its double Laplace transform in time and in spatial variable, and then implement a numerical Fourier inversion integration. Numerical experiments show that our algorithm gives accurate results within reasonable time and different shapes of spread curve can be obtained.

HERNÁNDEZ, CAMILO; JUNCA, MAURICIO. *Optimal dividend payments under a time of ruin constraint: exponential claims.* 136–142. We consider the optimal dividends problem under the Cramér-Lundberg model with exponential claim sizes subject to a constraint on the expected time of ruin. We introduce the dual problem and show that the complementary slackness conditions are satisfied, thus there is no duality gap. Therefore the optimal value function can be obtained as the point-wise infimum of auxiliary value functions indexed by Lagrange multipliers. We also present a series of numerical examples.

HU, XIANG; YANG, HAILIANG; ZHANG, LIANZENG. *Optimal retention for a stop-loss reinsurance with incomplete information.* 15–21. This paper considers the determination of optimal retention in a stop-loss reinsurance. Assume that we only have incomplete information on a risk X for an insurer, we use an upper bound for the value at risk (VaR) of the total loss of an insurer after stop-loss reinsurance arrangement as a risk measure. The adopted method is a distribution-free approximation which allows to construct the extremal random variables with respect to the stochastic dominance order and the stop-loss order. We derive the optimal retention such that the risk measure used in this paper attains the minimum. We establish the sufficient and necessary conditions for the existence of the nontrivial optimal stop-loss reinsurance. For illustration purpose, some numerical examples are included and compared with the results yielded in Theorem 2.1 of Cai and Tan (2007). [J. Cai, K.S. Tan (2007), Optimal retention for a stop-loss reinsurance under the VaR and CTE risk measures, ASTIN Bulletin 37(1): 93–112.]

HUYNH, MIRABELLE; LANDRIAULT, DAVID; SHI, TIANXIANG; WILLMOT, GORDON E. *On a risk model with claim investigation.* 37–45. In this paper, a queue-based claims investigation mechanism is considered to model an insurer's claim processing practices. The resulting risk model may be viewed as a first step in developing models with more realistic claim investigation mechanisms. Related to claim investigations, claim settlement delays and time dependent payments have been studied in a ruin context by, e.g. Taylor (1979) [G.C. Taylor (1979), Probability of ruin under inflationary conditions or under experience rating, Astin Bulletin 10(2): 149–162], Cai and Dickson (2002) [J. Cai, D.C.M. Dickson (2002), On the expected discounted penalty function at ruin of a surplus process with interest, Insurance Mathematics & Economics 30(3): 389–404], and Trufin et al. (2011) [J. Trufin, H. Albrecher, M. Denuit (2011), Ruin problems under IBNR dynamics, Applied Stochastic Models in Business and Industry 27(6): 619–632]. However, little has been done on queue-based investigation mechanisms. We first demonstrate the impact of a particular claim investigation system on some common ruin-related quantities when claims arrive according to a compound Poisson process, and investigation times are of a combination of exponential form. Probabilistic interpretations for the defective renewal equation components are also provided. Finally, via numerical examples, we explore various risk management questions related to this problem such as how claim investigation strategies can help an insurer control its activities within its risk appetite.

IGNATIEVA, KATJA; LANDSMAN, ZINOVIY. Estimating the tails of loss severity via conditional risk measures for the family of symmetric generalised hyperbolic distributions. 172–186. This paper addresses one of the main challenges faced by insurance companies and risk

management departments, namely, how to develop standardised framework for measuring risks of underlying portfolios and in particular, how to most reliably estimate loss severity distribution from historical data. This paper investigates tail conditional expectation (TCE) and tail variance premium (TVP) risk measures for the family of symmetric generalised hyperbolic (SGH) distributions. In contrast to a widely used Value-at-Risk (VaR) measure, TCE satisfies the requirement of the "coherent" risk measure taking into account the expected loss in the tail of the distribution while TVP incorporates variability in the tail, providing the most conservative estimator of risk. We examine various distributions from the class of SGH distributions, which turn out to fit well financial data returns and allow for explicit formulas for TCE and TVP risk measures. In parallel, we obtain asymptotic behaviour for TCE and TVP risk measures for large quantile levels. Furthermore, we extend our analysis to the multivariate framework, allowing multivariate distributions to model combinations of correlated risks, and demonstrate how TCE can be decomposed into individual components, representing contribution of individual risks to the aggregate portfolio risk.

LI, BO; NI, WEIHONG; CONSTANTINESCU, CORINA. *Risk models with premiums adjusted to claims number*. 94–102. Classical compound Poisson risk models consider the premium rate to be constant. By adjusting the premium rate to the claims history, one can emulate a Bonus-Malus system within the ruin theory context. One way to implement such adjustment is by considering the Poisson parameter to be a continuous random variable and use credibility theory arguments to adjust the premium rate a posteriori. Depending on the defectiveness of this random variable, respectively referred to as 'unforeseeable' (defective) versus 'historical' (non-defective) risks, one obtains different relations between the ruin probability with constant versus adjusted premium rate. A combination of these two kinds of risks also leads to a relation between the two ruin probabilities, when the a posteriori estimator of the number of claims is carefully chosen. Examples for specific claim sizes are presented throughout the paper.

LI, JINGCHAO; DICKSON, DAVID C M; LI, SHUANMING. *Some ruin problems for the MAP risk model*. 1–8. We consider ruin problems for a risk model with a Markovian arrival process (MAP). In particular, we study (1) the density of the time of ruin under two different assumptions on the premium income, by using two approaches; (2) the probability function of the number of claims until the time of ruin; (3) the moments of the time of ruin by developing a recursive approach.

LI, YONGWU; QIAO, HAN; WANG, SHOUYANG; ZHANG, LING. *Time-consistent investment strategy under partial information*. 187–197. This paper considers a mean-variance portfolio selection problem under partial information, that is, the investor can observe the risky asset price with random drift which is not directly observable in financial markets. Since the dynamic mean-variance portfolio selection problem is time inconsistent, to seek the time-consistent investment strategy, the optimization problem is formulated and tackled in a game theoretic framework. Closed-form expressions of the equilibrium investment strategy and the corresponding equilibrium value function under partial information are derived by solving an extended Hamilton-Jacobi-Bellman system of equations. In addition, the results are also given under complete information, which are need for the partial information case. Furthermore, some numerical examples are presented to illustrate the derived equilibrium investment strategies and numerical sensitivity analysis is provided.

LIANG, ZONGXIA; LONG, MINGSI. *Minimization of absolute ruin probability under negative correlation assumption*. 247–258. In this paper we consider the problem of minimizing the absolute ruin probability of an insurance company. The managers of the company control investment amount and risk exposure to minimize the absolute ruin probability. A negative

correlation between insurer's liabilities and capital gains in financial market is introduced. Under this negative correlation assumption, the explicit forms of the solutions and optimal strategies to this problem for all different parameters are derived. We find that the solutions of this problem are SS-shaped and the optimal strategies fail to be monotonic or continuous.

LIANG, ZONGXIA; SONG, MING. *Time-consistent reinsurance and investment strategies for mean-variance insurer under partial information.* 66–76. In this paper, based on equilibrium control law proposed by Björk and Murgoci (2010) [Björk, T, Murgoci, A, (2010). A general theory of Markovian time inconsistent stochastic control problems. (pre-print)], we study an optimal investment and reinsurance problem under partial information for insurer with mean-variance utility, where insurer's risk aversion varies over time. Instead of treating this time-inconsistent problem as pre-committed, we aim to find time-consistent equilibrium strategy within a game theoretic framework. In particular, proportional reinsurance, acquiring new business, investing in financial market are available in the market. The surplus process of insurer is depicted by classical Lundberg model, and the financial market consists of one risk free asset and one risky asset with unobservable Markov-modulated regime switching drift process. By using reduction technique and solving a generalized extended HJB equation, we derive closed-form time-consistent investment-reinsurance strategy and corresponding value function. Moreover, we compare results under partial information with optimal investment-reinsurance strategy when Markov chain is observable. Finally, some numerical illustrations and sensitivity analysis are provided.

LUUKKA, PASI; COLLAN, MIKAEL. *New fuzzy insurance pricing method for giga-investment project insurance.* 22–29. Large industrial investments, also called giga-investments, are a risky business and to attract financing they often require project insurance to mitigate risks. Giga-investments have long economic lives and can often steer their markets: information available is non-stochastic, normative, and often imprecise. The type of uncertainty that faces giga-investments is parametric and structural. We use possibility theory as a mathematical framework for modeling giga-investment profitability and based on the profitability models derive a new and intuitive four-step procedure for pricing giga-investment project insurance that is based on creating a pay-out distribution for the giga-investment project insurance contract. We present a set of numerical illustrations of insurance pricing with the new method.

MANESH, SIROUS FATHI; KHALEDI, BAHA-ELDIN. *Allocations of policy limits and ordering relations for aggregate remaining claims.* 9–14. Let $X_1,\ldots,X_n$ be a set of n risks, with decreasing joint density function f, faced by a policyholder who is insured for this n risks, with upper limit coverage for each risk. Let $[l] = (l_1,\ldots l_n)$ and $[l] = (l_1^*,\ldots l_n^*)$ be two vectors of policy limits such that $[l]$ is majorized by source l. It is shown that $\sum_{i=1}^{n}(X_i-l_i)_+$ is larger than $\sum_{i=1}^{n}(X_i-l_i^*)_+$ according to stochastic dominance if f is exchangeable. It is also shown that $\sum_{i=1}^{n}(X_i-l_{(i)})_+$ is larger than $\sum_{i=1}^{n}(X_i-l_{(i)}^*)_+$ according to stochastic dominance if either f is a decreasing arrangement or $X_1,\ldots,X_n$ are independent and ordered according to the reversed hazard rate ordering. We apply the new results to multivariate Pareto distribution.

OROZCO-GARCIA, CAROLINA; SCHMEISER, HATO. *How sensitive is the pricing of lookback and interest rate guarantees when changing the modelling assumptions?* 77–93. This paper aims to give detailed insights into the price sensitivity of embedded investment guarantees provided by unit-linked life insurance products. Particularly, it analyzes the model and parameter risk from the provider's perspective. We compare two different forms of investment guarantees: Interest Rate Guarantees (IRG) and Lookback Guarantees (LBG). Via Monte Carlo simulation, the prices of the

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embedded investment guarantees are estimated assuming the underlying to evolve according to a normal or double-exponential jump-diffusion model. The input parameters are derived from empirical data for various asset classes. In a first step, the parameters of the IRG and the LBG are adjusted such the prices of these two guarantees are equal. In a second step, a detailed comparison is made between the price sensitivities of both guarantee forms when the initial modelling parameters are changed. Finally, we investigate how parameter changes affect the investor payoff under the different guarantee forms and model assumptions used for the dynamic of the underlying.

SCHOLZ, MICHAEL; NIELSEN JENS PERCH; SPERLICH, STEFAN. *Nonparametric prediction of stock returns based on yearly data: the long-term view*. 143–155. One of the most studied questions in economics and finance is whether empirical models can be used to predict equity returns or premiums. In this paper, we take the actuarial long-term view and base our prediction on yearly data from 1872 through 2014. While many authors favor the historical mean or other parametric methods, this article focuses on nonlinear relationships between a set of covariates. A bootstrap test on the true functional form of the conditional expected returns confirms that yearly returns on the S&P500 are predictable. The inclusion of prior knowledge in our nonlinear model shows notable improvement in the prediction of excess stock returns compared to a fully nonparametric model. Statistically, a bias and dimension reduction method is proposed to import more structure in the estimation process as an adequate way to circumvent the curse of dimensionality.

SOKOL, ALEXANDER. *A generic model for spouse's pensions with a view towards the calculation of liabilities*. 198-207. We introduce a generic model for spouse's pensions. The generic model allows for the modeling of various types of spouse's pensions with payments commencing at the death of the insured. We derive abstract formulas for cashflows and liabilities corresponding to common types of spouse's pensions. In particular, we show that our generic model allows for simple modeling of longevity improvements, enabling the calculation of the Solvency II capital requirements related to longevity risk for spouse's pensions.

TORRES, RAÚL; LILLO, ROSA E; LANIADO, HENRY. *A directional multivariate value at risk*. 111–123. In economics, insurance and finance, value at risk (VaR) is a widely used measure of the risk of loss on a specific portfolio of financial assets. For a given portfolio, time horizon, and probability a, the 100a% VaR is defined as a threshold loss value, such that the probability that the loss on the portfolio over the given time horizon exceeds this value is a. That is to say, it is a quantile of the distribution of the losses, which has both good analytic properties and easy interpretation as a risk measure. However, its extension to the multivariate framework is not unique because a unique definition of multivariate quantile does not exist. In the current literature, the multivariate quantiles are related to a specific partial order considered in R^n, or to a property of the univariate quantile that is desirable to be extended to R^n. In this work, we introduce a multivariate value at risk as a vector-valued directional risk measure, based on a directional multivariate quantile, which has recently been introduced in the literature. The directional approach allows the manager to consider external information or risk preferences in her/his analysis. We derive some properties of the risk measure and we compare the univariate VaR over the marginals with the components of the directional multivariate VaR. We also analyze the relationship between some families of copulas, for which it is possible to obtain closed forms of the multivariate VaR that we propose. Finally, comparisons with other alternative multivariate VaR given in the literature, are provided in terms of robustness.

WONG, CHI HEEM; TSUI, ALBERT K C. *Forecasting life expectancy: evidence from a new survival function*. 208–226. We propose a new survival function to forecast life expectancies at

various ages. The proposed model comprises the youth-to-adulthood component and the old-to-oldest-old component. It is able to closely fit adult survivorship of the US men and women in the period from 1950 to 2010. We find evidence that the forecasting performance of life expectancies by the proposed model compares favorably with those obtained from the popular Lee-Carter model (1992) and the shifting logistic model proposed by Bongaarts (2005). [J. Bongaarts, Long-range trends in adult mortality: models and projection methods, Demography (2005) 42(1): 23–49]

WONG, JEFF T; CHEUNG, ERIC C K. *On the time value of Parisian ruin in (dual) renewal risk processes with exponential jumps.* 280–290. This paper studies the Parisian ruin problem first proposed by Dassios and Wu (2008a,b) [Dassios, A., Wu, S. (2008a), Parisian ruin with exponential claims. Preprint available at http://stats.lse.ac.uk; Dassios, A., Wu, S. (2008b). Ruin probabilities of the Parisian type for small claims. Preprint available at http://stats.lse.ac.uk], where the Parisian ruin time is defined to be the first time when the surplus process has stayed below zero continuously for a pre-specified time length dd. Both the insurance risk process and the dual model will be considered under exponential distributional assumption on the jump sizes while keeping the inter-arrival times arbitrary. In these two models, the Laplace transform of the Parisian ruin time is derived by extending the excursion techniques in Dassios and Wu (2008a) and taking advantage of the memoryless property of exponential distributions. Our results are represented in integral forms, which are expressed in terms of the (joint) densities of various ruin-related quantities that are available in the literature or obtainable using the Lagrange's expansion theorem. As a by-product, we also provide the joint distribution of the numbers of periods of negative surplus that are of duration more than dd and less than dd, which can be obtained using some of our intermediate results. The case where the Parisian delay period dd is replaced by a random time is also discussed, and it is applied to find the Laplace transform of the occupation time when the surplus is negative. Numerical illustrations concerning an Erlang(2) insurance risk model are given at the end.

ZHANG, YIYANG; ZHAO, PENG. *Comparisons on aggregate risks from two sets of heterogeneous portfolios.* 124–135. In this paper, we stochastically compare the aggregate risks from two heterogeneous portfolios. It is shown that under suitable conditions the more hetero-geneities among aggregate risks would result in larger aggregate risks in the sense of the stochastic order. The stochastic properties of aggregate risks when the claims follow proportional hazard rates models or scale models are studied. We also provide sufficient conditions for comparing the aggregate risks arising from two sets of heterogeneous portfolios with claims having gamma distributions. In particular, the aggregate risks of portfolios from dependent samples with comonotonic dependence structures or arrangement increasing density functions are discussed. The new results established strengthen and generalize several results known in the literature including Ma (2000), Khaledi and Ahmadi (2008), Xu and Hu (2011), Xu and Balakrishnan (2011), Pan et al. (2013) and Barmalzan et al. (2015). [C. Ma, Convex orders for linear combinations of random variables, Journal of Statistical Planning and Inference (2000) 84: 11–25] [B. Khaledi, S.S. Ahmadi, On stochastic comparison between aggregate claim amounts, Journal of Statistical Planning and Inference (2008) 138: 3121–3129] [M. Xu, T. Hu, Some inequalities of linear combinations of independent random variables — I, Journal of Applied Probability (2011) 48: 1179–1188] [M. Xu, N. Balakrishnan, On the convolution of heterogeneous Bernoulli random variables, Journal of Applied Probability 48 (2011): 877–884] [X. Pan, M. Xu, T. Hu, Some inequalities of linear combinations of independent random variables —- II, Bernoulli (2013)19: 1176–1789] [G. Barmalzan, A.T.P. Najafabadi, N. Balakrishnan, Stochastic comparison of aggregate claim amounts between two heterogeneous portfolios and its applications, Insurance Mathematics & Economics (2015), 61: 235–241]

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FARRELL, MARK; GALLAGHER, RONAN. *The valuation implications of Enterprise Risk Management maturity*. 626–657. Enterprise Risk Management (ERM) is the discipline by which enterprises monitor, analyze, and control risks from across the enterprise, with the goal of identifying underlying correlations and thus optimizing the risk-taking behavior in a portfolio context. This study analyzes the valuation implications of ERM Maturity. We use data from the industry leading Risk and Insurance Management Society Risk Maturity Model over the period from 2006 to 2011, which scores firms on a five-point maturity scale. Our results suggest that firms that have reached mature levels of ERM are exhibiting a higher firm value, as measured by Tobin's Q. We find a statistically significant positive relation to the magnitude of 25 percent. Upon decomposition of the maturity score, we find that the most important aspects of ERM from a valuation perspective relate to the level of top–down executive engagement and the resultant cascade of ERM culture throughout the firm. Firms that have successfully integrated the ERM process into both their strategic activities and everyday practices display superior ability in uncovering risk dependencies and correlations across the entire enterprise and as a consequence enhanced value when undertaking the ERM maturity journey ceteris paribus.

HSU, WEN-YEN; HUANG, YENYU (REBECCA); LAI, GENE. *Corporate governance and cash holdings: evidence from the U.S. property–liability insurance industry*. 715–748. This article examines the impact of board and finance committee characteristics on insurers' cash holdings using a sample of 1,454 U.S. stock property–liability insurer-year observations. We focus on the roles of independent board members and independent finance committee members. Our results suggest that independent board members allow managers to hold excess cash holdings to avoid underinvestment and play a monitoring role in managers' cash spending behavior in a regulated industry. The overall findings are consistent with the independent director responsibility hypothesis, which suggests that independent directors play a monitoring role in managers' cash spending behavior and avoiding underinvestment problems.

LIN, YIJIA; YU, JIFENG; PETERSON, MANFERD O. *Reinsurance networks and their impact on reinsurance decisions: theory and empirical evidence*. 531–569. This article investigates the role of reinsurance networks in an insurer's reinsurance purchase decision. Drawing on network theory, we develop a framework that delineates how the pattern of linkages among reinsurers determines three reinsurance costs (loadings, contagion costs, and search and monitoring costs) and characterizes an insurer's optimal network structure. Consistent with empirical evidence based on longitudinal data from the U.S. property and casualty insurance industry, our model predicts an inverted U-shaped relationship between the insurer's optimal percentage of reinsurance ceded and the number of its reinsurers. Moreover, we find that a linked network may be optimal ex ante even though linkages among reinsurers may spread financial contagion, supporting the model's

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prediction regarding social capital benefits associated with network cohesion. Our theoretical model and empirical results have implications for other networks such as loan sale market networks and over-the-counter dealer networks.

MICHEL-KERJAN, ERWANN; RASCHKY, PAUL; KUNREUTHER, HOWARD. *Corporate demand for insurance: new evidence from the U.S. Terrorism and property markets.* 505–530. Since the passage of the Terrorism Risk Insurance Act of 2002, corporate terrorism insurance is sold as a separate policy from commercial property coverage. In this article, we determine whether companies differ in their demand for property and terrorism insurance. Using a unique data set of insurance policies purchased by large U.S. firms, combined with financial information of the corporate clients and of the insurance provider, we apply a two-stage least squares approach to obtain consistent estimates of premium elasticity of corporate demand for property and terrorism coverage. Our findings suggest that both are rather price inelastic and that corporate demand for terrorism insurance is significantly more price inelastic than demand for property insurance. We further find a negative relation between the solvency ratios of both property and terrorism risk coverage, with a stronger effect on the latter, indicating that companies use their ability to self-insure as a substitute for market insurance. Our results are robust to the application of alternative estimators as well as changes in the econometric specifications. [See also Corrigendum published in 82 (4), p989–990]

PORTH, LYSA; PAI, JEFFREY; BOYD, MILTON. *A portfolio optimization approach using combinatorics with a genetic algorithm for developing a reinsurance model.* 687–713. Some insurance firms challenged with a portfolio of high-variance risks face the classic trade-off between risk spreading and risk retaining. Using crop insurance as an example, a new solution to this problem is undertaken to uncover an improved reinsurance design. Joint self-managed reinsurance pooling and private reinsurance are combined in a portfolio approach utilizing combinatorial optimization with a genetic algorithm (Model C), achieving high surplus, high survival probability, and low deficit at ruin. This portfolio model may also be useful for other large natural disaster and weather-related insurance portfolios, and other portfolio applications.

SCHMEISER, HATO; WAGNER, JOËL. *A proposal on how the regulator should set minimum interest rate guarantees in participating life insurance contracts.* 659–686. We consider a contingent claim model framework for participating life insurance contracts and assume a competitive market with minimum solvency requirements as provided by Solvency II. In a first step, the implications of the regulator's imposing a particular interest rate guarantee on the insurer's asset allocation are analyzed in a reference situation. We study the sensitivity of the interaction between the interest rate guarantee and the asset allocation when the risk-free interest rate changes. Particular attention is paid to the current market situation where the guaranteed interest rate is often close to the risk-free interest rate. In a second step, we assess at what level the interest rate guarantee should be set by the regulator in order to maximize policyholders' utility. We show that the results yielded by the proposed concept to derive an optimal value for the interest rate guarantee are very stable for various model parameters.

UPADHYAY, ARUN. *Board size, firm risk, and equity discount.* 571–599. Prior literature documents that larger boards pursue conservative investment policies and that their decision outcomes are moderate, which promote an environment of risk aversion. I argue that this risk aversion hurts equity holders when firms hold a larger amount of long-term debt. Addressing potential endogeneity problems associated with board size, I find an equity discount associated with larger boards in firms that have greater amounts of long-term debt. On the other hand, larger boards are associated with an equity premium when firms have a greater short-term debt-to-assets

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ratio. The equity discount associated with larger boards disappears in firms with no long-term debt. Further analysis also indicates that firms with larger boards enjoy a better credit rating and a lower realized cost of debt. Overall, analysis in this study suggests that the association between board size and equity value is a function of a firm's debt structure.

VAN DER VEER, KOEN J M. *The private export credit insurance effect on trade.* 601–624. International trade relies on trade finance (credit or insurance) by financial institutions. Evidence on the link between trade finance and trade is scarce, however, because trade finance data are hard to come by. This article uses a unique bilateral data set on worldwide exports insured by a world's leading private trade credit insurer in the period from 1992 to 2006. Applying various trade models, I consistently find a positive and statistically significant effect of private export credit insurance on exports. The results suggest that the private export credit insurance effect on trade is larger than the value of exports insured.

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BOYER, M MARTIN; TENNYSON, SHARON. Directors' and officers' liability insurance, corporate risk and risk taking: new panel data evidence on the role of directors' and officers' liability insurance. 753–791. This article develops and tests hypotheses regarding the relationship between directors' and officers' (D&O) insurance purchase and firm size, governance characteristics, and business risk, using a unique panel data set on Canadian firms for years 1996–2005. The data permit examination of the determinants of insurance pricing, ownership and coverage limits, and the effects of insurance on board characteristics and earnings management. Results using panel data methods and controlling for endogenous prices and endogenous selection into insurance ownership provide strong statistical evidence for the view that D&O insurance markets take corporate risk into account, but that insurance leads to greater risk taking.

CHEN, HUA; HSU, WEN-YEN; WEISS, MARY A. *The pension option in labor insurance and its effect on household saving and consumption: evidence from Taiwan.* 947–975. Starting in 2009, the Labor Insurance (LI) program in Taiwan has allowed workers to choose between pension old-age benefits and one-time old-age benefits. The introduction of the pension option not only mitigates longevity risk for workers but also provides a higher expected present value of old-age benefits to workers than the one-time benefit option (on average). Based on a lifecycle model with uncertain lifespan, we expect that workers will increase current consumption and reduce saving in response to this policy intervention. We use data from the Survey of Family Income and Expenditure in Taiwan to empirically test this prediction. In order to isolate other systematic structural changes or economic shocks from the true impact of the pension option on saving and consumption, we adopt a difference-in-differences approach in this study. Our results indicate that the implementation of pension benefits in LI lowers households' saving by 8.41 percent (NT$50,587) and raises consumption by 5.73 percent (NT$42,897) for LI workers. In addition, we find that, in general, households with less saving or consumption tend to be more responsive to this policy in terms of reducing saving or increasing consumption.

EGGER, PETER; RADULESCU, DOINA; REES, RAY. *Heterogeneous beliefs and the demand for D&O insurance by listed companies.* 823–852. This article introduces a new rationale for the existence of

"directors' and officers" (D&O) insurance. We use a model with volatile stock markets where shareholders design compensation schemes that incentivize managers to stimulate short-term increases in stock prices that do not maximize long-run stock market value. We show that D&O insurance provides a convenient instrument for the initial shareholders of a company to take advantage of differences in beliefs between insiders and outsiders in capital markets. The empirical results support the idea that both the insurance coverage and the premium are higher in the presence of new shareholders and volatile markets. The results prove robust in various empirical model specifications.

GERUSO, MICHAEL; ROSEN, HARVEY S. *Insurance fraud in the workplace? evidence from a dependent verification program.* 921–946. Many employers have implemented dependent verification (DV) programs, which aim to reduce employee benefits costs by ensuring that ineligible persons are not enrolled in their health insurance plans as dependents. We evaluate a DV program using a panel of health plan enrollment data from a large, single-site employer. We find that dependents were 2.7 percentage points less likely to be reenrolled in the year that DV was introduced, indicating that this fraction of dependents was ineligibly enrolled prior to the program's introduction. There is some evidence consistent with the notion that these dependents were actually ineligible, rather than merely discouraged from reenrollment by compliance costs. We find no indication that the removal of these ineligible dependents spilled over to affect the enrollment of eligible dependents within the same family.

GILLAN, STUART L; PANASIAN, CHRISTINE A. *On lawsuits, corporate governance, and directors' and officers' liability insurance.* 793–822. We examine whether information about firms' directors' and officers' (D&O) liability insurance coverage provides insights into the likelihood of shareholder lawsuits. Using Canadian firms, we find evidence that firms with D&O insurance coverage are more likely to be sued and that the likelihood of litigation increases with increased coverage. These findings are consistent with managerial opportunism or moral hazard related to the insurance purchase decision. We also find that higher premiums are associated with the likelihood of litigation, indicating that insurers price this behavior. Taken together, the findings suggest that coverage and premium levels have the potential to convey information about lawsuit likelihood, and a firm's governance quality, to the marketplace.

NYCE, CHARLES; DUMM, RANDY E; SIRMANS, G STACY; SMERSH, GREG. *The capitalization of insurance premiums in house prices.* 891–919. This study uses Miami-Dade County, Florida home sales, and Citizens Property Insurance Corporation data for the period 2004 through 2009 to measure the capitalization effect of increases in premiums on house prices. Using hedonic pricing models, spatial autocorrelation models, and difference-in-differences models, we find that new information was conveyed to homeowners in the higher risk areas by the 2004/2005 storms and that consumers appear to use the insurance premium as a "risk signal." We also find some support for the hypothesis that the risk of potential hurricane losses is communicated to potential homebuyers through windzone maps.

STEPHENS, ERIC; THOMPSON, JAMES R. *Separation without exclusion in financial insurance.* 853–864. This article develops a model of linearly priced financial insurance sold by default-prone insurers. It shows that when insurers differ in their default probabilities there can exist equilibria in which different risk types partially or completely self-sort into insurance contracts offered by different insurers. Partial separation can occur when insurer default and insurance risks are uncorrelated. Full separation is possible when they are correlated. For example, low-risk insured parties may match with higher default-risk insurers, while high-risk insured parties match with lower default-risk insurers.

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WANG, JIANLI; LI, JINGYUAN. *Precautionary effort: another trait for prudence.* 977–983. This article shows that, in the temporal model of Eeckhoudt, Huang, and Tzeng (2012), prudence alone is sufficient to obtain a precautionary effort. Moreover, our conclusions relax the assumption of the convexity of loss probability. We further analyze the effect of the introduction or deterioration of background risks on precautionary effort in different settings.

ZAVADIL, TIBOR. *Do the better insured cause more damage? Testing for asymmetric information in car insurance.* 865–889. This article tests for the presence of asymmetric information in Dutch car insurance among senior drivers using several nonparametric tests based on conditional-correlation approach. Since asymmetric information implies that more comprehensive coverage is associated with higher risk, we examine whether the better insured have a higher frequency of claims or cause more severe accidents. Using data on claim occurrences, incurred losses and written premiums, and controlling for the insureds' experience rating, we do not find any evidence of asymmetric information in this market.

North American Actuarial Journal

19 (3), 2015

BAYRAKTAR, ERHAN; PROMISLOW, S DAVID; YOUNG, VIRGINIA R. *Purchasing term life insurance to reach a bequest goal: time-dependent case.* 224–236. We consider the problem of how an individual can use term life insurance to maximize the probability of reaching a given bequest goal, an important problem in financial planning. We assume that the individual buys instantaneous term life insurance with a premium payable continuously. We allow the force of mortality to vary with time, which, as we show, greatly complicates the problem.

GAVRILOV, LEONID A; GAVRILOVA, NATALIA S. *Predictors of exceptional longevity: effects of early-life and midlife conditions, and familial longevity.* 174–186. Knowledge of strong predictors of mortality and longevity is very important for actuarial science and practice. Earlier studies found that parental characteristics as well as early-life conditions and midlife environment play a significant role in survival to advanced ages. However, little is known about the simultaneous effects of these three factors on longevity. This ongoing study attempts to fill this gap by comparing centenarians born in the United States in 1890–1891 with peers born in the same years who died at age 65. The records for centenarians and controls were taken from computerized family histories, which were then linked to 1900 and 1930 U.S. censuses. As a result of this linkage procedure, 765 records of confirmed centenarians and 783 records of controls were obtained. Analysis with multivariate logistic regression found the existence of both general and gender-specific predictors of human longevity. General predictors common for men and women are paternal and maternal longevity. Gender-specific predictors of male longevity are occupation as a farmer at age 40, Northeastern region of birth in the United States, and birth in the second half of year. A gender-specific predictor of female longevity is the availability of radio in the household according to the 1930 U.S. census. Given the importance of familial longevity as an independent predictor of survival to advanced ages, we

conducted a comparative study of biological and nonbiological relatives of centenarians using a larger sample of 1,945 validated U.S. centenarians born in 1880–1895. We found that male gender of centenarian has a significant positive effect on survival of adult male relatives (brothers and fathers) but not female blood relatives. Life span of centenarian siblings-in-law is lower compared to life span of centenarian siblings and does not depend on centenarian gender. Wives of male centenarians (who share lifestyle and living conditions) have a significantly better survival compared to wives of centenarians' brothers. This finding demonstrates an important role of shared familial environment and lifestyle in human longevity. The results of this study suggest that familial background, some early-life conditions and midlife characteristics play an important role in longevity.

GUTTERMAN, SAM. *Mortality of smoking by gender*. 200–223. Exposure to cigarette smoke has had and will continue to have a huge effect on mortality. Significant differences in smoking prevalence rates by gender have contributed to varying levels and rates of improvement in mortality over the last several decades and are expected to continue to influence mortality improvement differently over the next several decades. The combined effect of greater historical smoking prevalence rates by males and their corresponding earlier and larger reduction has in part been responsible for the recent improvement in mortality rates for males compared to that for females in the United States. Similar patterns are evident in almost all economically developed countries, although their timing and levels differ. The patterns in less-developed countries will likely follow similar patterns as concerns emerge about the effect of smoking on the mortality of their citizens. The objective of this article is to compare smoking prevalence and cessation by gender and the effect on smoking-attributable and, in turn, all-cause mortality. A summary of mortality attribution approaches used to enhance the evaluation of the effect of smoking and projections of mortality rates by gender is also provided.

RAMSAY, COLIN M; OGULEDO, VICTOR I. *Optimal disability insurance with moral hazards: absenteeism, presenteeism, and shirking*. 143–173. Presenteeism occurs when employees are present at the workplace but cannot perform at their best because of ill-health or other reasons, while absenteeism occurs when employees are absent from the workplace. Although absenteeism is important, researchers now say presenteeism can be more costly to businesses and may be responsible for as much as three times the health-related lost productivity as compared to absenteeism and may cost the U.S. economy as much as $150 billion per year. Given the cost of absenteeism and presenteeism, one of the objectives of this article is to provide actuaries with the techniques and insights needed to design disability insurance policies that take into account the dynamics of absenteeism and presenteeism. To this end we develop a simple multistate sickness-disability model of the evolution of an employee's health over time. We assume employees receive sick pay, the size of which depends on their health state, and there is a government-sponsored unemployment insurance program. In our model it is possible for employees in good health to avoid work by staying home, which is called shirking. To reduce shirking, the employer decides to check the health status of a certain percentage of employees who "call in sick." Given the sick-pay structure, the probability of a health check, and the existence of unemployment insurance, employees develop rational strategies about whether to engage in shirking, absenteeism, or presenteeism. These strategies are captured in a set of Volterra integral equations. We use these Volterra integral equations to show how the employer can design a disability insurance plan that can incentivise employees to eliminate shirking and to act in a manner that will maximize the employer's expected profits.

WANG, HSIN CHUNG; YUE, JACK C. *Mortality, health, and marriage: a study based on Taiwan's population data*. 187–199. Life expectancy has been increasing significantly since the start of the 20th century, and mortality improvement trends are likely to continue in the 21st century.

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Stochastic mortality models are used frequently to predict the expansion in life expectancy. In addition to gender, age, period, and cohort are the three main risk factors considered in constructing mortality models. Other than these factors, it is also believed that marital status is related to health and longevity, and many studies have found that married persons have a lower mortality rate than the unmarried. In this study, we have used Taiwan's marital data for the whole population (married, unmarried, divorced/widowed) to evaluate if the marital status can be a preferred criteria. Furthermore, we also want to know whether the preferred criteria will be valid in the future. We chose two popular mortality models, the Lee-Carter and age-period-cohort, to model the mortality improvements for various marital statuses. Because of a linear dependence in the parameters of the age-period-cohort model, we used a computer simulation to choose the appropriate estimation method. Based on Taiwan's marital data, we found that married persons have significantly lower mortality rates than the single, and if converting the difference into a life insurance policy, the discount amount is even larger than that for smokers/nonsmokers.

North American Actuarial Journal

19 (4), 2015

CAI, XIAOQIANG; WEN, LIMIN; WU, XIANYI; ZHOU, XIAN. *Credibility estimation of distribution functions with applications to experience rating in general insurance.* 311–335. This article presents a new credibility estimation of the probability distributions of risks under Bayes settings in a completely nonparametric framework. In contrast to the Ferguson's Bayesian nonparametric method, it does not need to specify a mathematical form of the prior distribution (such as a Dirichlet process). We then show the applications of the method in general insurance premium pricing, a procedure commonly known as experience rating, which utilizes the insured's claim experience to calculate a proper premium under a given premium principle (referred to as a risk measure). As this method estimates the probability distributions of losses, not just the means and variances, it provides a unified nonparametric framework to experience rating for arbitrary premium principles. This encompasses the advantages of the well-known Bühlmann's and Ferguson's approaches, while it overcomes their drawbacks. We first establish a linear Bayes method and prove its strong consistency in nonparametric settings that require only knowledge of the first two moments of the loss distributions considered as a stochastic process. Then an empirical Bayes method is developed for the more general situation where a portfolio of risks is observed but no knowledge is available or assumed on their loss and prior distributions, including their moments. It is shown to be asymptotically optimal. The performance of our estimates in comparison with traditional methods is also evaluated through theoretical analysis and numerical studies, which show that our approach produces premium estimates close to the optima.

GODECHARLE, ELS; ANTONIO, KATRIEN. *Reserving by conditioning on markers of individual claims: a case study using historical simulation.* 273–288. This article explores the use of claim specific characteristics, so-called claim markers, for loss reserving with individual claims. Starting from the approach of Rosenlund and using the technique of historical simulation we develop a stochastic Reserve by Detailed Conditioning method that is applicable to a microlevel data set with detailed information on individual claims. We construct the predictive distribution of the outstanding loss reserve by simulating future payments of a claim, given its claim markers. We demonstrate the performance of the method on a portfolio of general liability insurance policies for private individuals from a European insurance company. Hereby we explore how to incorporate different kinds of claim markers and evaluate the impact of the set of markers and their specification on the predictive distribution of the outstanding reserve.

POON, JIMMY; LU, YI. *A spatial cross-sectional credibility model with dependence among risks.* 289–310. A Bühlmann-Straub type credibility model with dependence structure among risk parameters and conditional spatial cross-sectional dependence is studied. Predictors of future losses for the model under both types of dependence are derived by minimizing the expected quadratic loss function, and nonparametric estimators of structural parameters are considered in the spatial statistics context. Predictions and estimations made for the proposed model are examined and compared to other models in an application with crop insurance data and in a simulation study.

ZENG, XUDONG; WANG, YULING; CARSON, JAMES M. *Dynamic portfolio choice with stochastic wage and life insurance.* 256–272. We study optimal insurance, consumption, and portfolio choice in a framework where a family purchases life insurance to protect the loss of the wage earner's human capital. Explicit solutions are obtained by employing constant absolute risk aversion utility functions. We show that the optimal life insurance purchase is not a monotonic function of the correlation between the wage and the financial market. Meanwhile, the life insurance decision is explicitly affected by the family's risk preferences in general. The model also predicts that a family uses life insurance and investment portfolio choice to hedge stochastic wage risk.

ZHU, ZHIWEI; LI, ZHI; WYLDE, DAVID; FAILOR, MICHAEL; HRISCHENKO, GEORGE. *Logistic regression for insured mortality experience studies.* 241–255. Properly adapted statistical modeling methodology can be a powerful tool for coping with a broad range of challenges related to life and annuity insurance industries' experience studies. In this article, we present a logistic regression model based on U.S. insured mortality experience study with a focus on gaining study efficiency and effectiveness by addressing multiple analytical predicaments within one statistical modeling framework. These predicaments include but are not limited to (a) testing statistical significances or credibility of potential mortality drivers, (b) estimation of normalized mortality, slopes, and differentials, (c) quantification of study reliability, and (d) extrapolation for under-experienced mortality, smoothing between select and ultimate estimations, and development of basic experience tables.

Scandinavian Actuarial Journal

5, 2015

COSTABILE, MASSIMO; MASSABÒ, IVAR; RUSSO, EMILIO. *Computing finite-time survival probabilities using multinomial approximations of risk models.* 406–422. We consider the problem of computing finite-time survival probabilities for various risk models. We develop an approximating discrete-time multinomial lattice that mimics the evolution of the corresponding continuous risk process. A simple recursive algorithm to compute survival probabilities is described. Numerical results show that the proposed scheme yields accurate values in all the considered cases.

FENG, RUNHUAN; VOLKMER, HANS W; ZHANG, SHUAIQI; ZHU, CHAO. *Optimal dividend policies for piecewise-deterministic compound Poisson risk models.* 423–454. This paper considers

the optimal dividend payment problem in piecewise-deterministic compound Poisson risk models. The objective is to maximize the expected discounted dividend payout up to the time of ruin. We provide a comparative study in this general framework of both restricted and unrestricted payment schemes, which were only previously treated separately in certain special cases of risk models in the literature. In the case of restricted payment scheme, the value function is shown to be a classical solution of the corresponding HJB [Hamilton-Jacobi-Bellman] equation, which in turn leads to an optimal restricted payment policy known as the threshold strategy. In the case of unrestricted payment scheme, by solving the associated integro-differential quasi-variational inequality, we obtain the value function as well as an optimal unrestricted dividend payment scheme known as the barrier strategy. When claim sizes are exponentially distributed, we provide easily verifiable conditions under which the threshold and barrier strategies are optimal restricted and unrestricted dividend payment policies, respectively. The main results are illustrated with several examples, including a new example concerning regressive growth rates.

MARTÍNEZ MIRANDA, MARÍA DOLORES; NIELSEN, JENS PERCH; VERRALL, RICHARD J; WÜTHRICH, MARIO V. *Double chain ladder, claims development inflation and zero-claims.* 383–405. Double chain ladder demonstrated how the classical chain ladder technique can be broken down into separate components. It was shown that under certain model assumptions and via one particular estimation technique, it is possible to interpret the classical chain ladder method as a model of the observed number of counts with a built-in delay function from when a claim is reported until it is paid. In this paper, we investigate the double chain ladder model further and consider the case when other knowledge is available, focusing on two specific types of prior knowledge, namely prior knowledge on the number of zero-claims for each underwriting year and prior knowledge about the relationship between the development of the claim and its mean severity. Both types of prior knowledge readily lend themselves to be included in the double chain ladder framework.

ZHANG, LIANZENG; HU, XIANG; DUAN, BAIGE. *Optimal reinsurance under adjustment coefficient measure in a discrete risk model based on Poisson MA(1) process.* 455–467. In this paper, we study the retention levels for combinations of quota-share and excess of loss reinsurance by maximizing the insurer's adjustment coefficient, which in turn minimizes the asymptotic result of ruin probability. Assuming that the premiums are determined by the expected value principle, we consider a discrete risk model, in which a dependence structure is introduced based on Poisson MA(1) process between the claim numbers for each period. The impact of dependence parameter on the adjustment coefficient is discussed and numerical examples are provided to illustrate the results obtained in this paper.

Scandinavian Actuarial Journal

6, 2015

COORAY, KAHADAWALA; CHENG, CHIN-I. *Bayesian estimators of the lognormal-Pareto composite distribution.* 500-515. In this paper, Bayesian methods with both Jeffreys and conjugate priors for estimating parameters of the lognormal–Pareto composite (LPC) distribution are considered. With Jeffreys prior, the posterior distributions for parameters of interest are derived and their properties are described. The conjugate priors are proposed and the conditional posterior distributions are provided. In addition, simulation studies are performed to obtain the upper percentage points of Kolmogorov-Smirnov and Anderson-Darling test statistics. Furthermore, these statistics are used to compare Bayesian and likelihood estimators. In order to clarify

and advance the validity of Bayesian and likelihood estimators of the LPC distribution, well-known Danish fire insurance data-set is reanalyzed.

DEBICKI, KRZYSZTOF; HASHORVA, ENKELEJD; JI, LANPENG. *Gaussian risk models with financial constraints*. 469–481. In this paper, we investigate Gaussian risk models which include financial elements, such as inflation and interest rates. For some general models for inflation and interest rates, we obtain an asymptotic expansion of the finite-time ruin probability for Gaussian risk models. Furthermore, we derive an approximation of the conditional ruin time by an exponential random variable as the initial capital tends to infinity.

POWERS, MICHAEL R; POWERS, THOMAS Y. *Fourier-analytic measures for heavy-tailed insurance losses*. 527–547. We propose a family of three 'Fourier-analytic' measures to extend the conventional concepts of standard deviation, variance, and coefficient of variation to insurance losses with arbitrarily heavy tails. After motivating and computing their mathematical forms, we apply the proposed measures to the case of Lévy-stable loss portfolios. Finally, the new measures are used to study the diversification properties of heavy-tailed losses.

SCHIEGL, MAGDA. *A model study about the applicability of the Chain Ladder method*. 482–499. Loss Reserving is a major topic of actuarial sciences with a long tradition and well-established methods – both in science and in practice. With the implementation of Solvency II, stochastic methods and modelling the stochastic behaviour of individual claim portfolios will receive additional attention. The author has recently proposed a three-dimensional (3D) stochastic model of claim development. It models a reasonable claim process from first principle by integrating realistic processes of claim occurrence, claim reporting and claim settlement. This paper investigates the ability of the Chain Ladder (CL) method to adequately forecast outstanding claims within the framework of the 3D model. This allows one to find conditions under which the CL method is adequate for outstanding claim prediction, and others in which it fails. Monte Carlo (MC) simulations are performed, lending support to the theoretic results. The analysis leads to additional suggestions concerning the use of the CL method.

WÜTHRICH, MARIO V. *From ruin theory to solvency in non-life insurance*. 516–526. We start from ruin theory considerations in the classical Cramér-Lundberg model. We modify these considerations step by step so that finally we arrive at today's solvency assessments for non-life insurance companies. These modifications include discussions about time horizons, risk measures, financial returns, and valuation of insurance liabilities.

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7, 2015

BLADT, MOGENS; NIELSEN, BO FRIIS; SAMORODNITSKY, GENNADY. *Calculation of ruin probabilities for a dense class of heavy tailed distributions*. 573–591. In this paper, we propose a class of infinite-dimensional phase-type distributions with finitely many parameters as models for heavy tailed distributions. The class of finite-dimensional phase-type distributions is dense in the class of distributions on the positive reals and may hence approximate any such distribution. We prove that formulas from renewal theory, and with a particular attention to ruin probabilities, which are true for common phase-type distributions also hold true for the infinite-dimensional case. We provide algorithms for calculating functionals of interest such as the renewal density and

the ruin probability. It might be of interest to approximate a given heavy tailed distribution of some other type by a distribution from the class of infinite-dimensional phase-type distributions and to this end we provide a calibration procedure which works for the approximation of distributions with a slowly varying tail. An example from risk theory, comparing ruin probabilities for a classical risk process with Pareto distributed claim sizes, is presented and exact known ruin probabilities for the Pareto case are compared to the ones obtained by approximating by an infinite-dimensional hyper-exponential distribution.

GUILLOU, ARMELLE; NAVEAU, PHILIPPE; YOU, ALEXANDRE. *A folding methodology for multivariate extremes: estimation of the spectral probability measure and actuarial applications.* 549–572. In this paper, the folding methodology developed in the context of univariate Extreme Value Theory (EVT) by You et al. is extended to a multivariate framework. Under the usual EVT assumption of regularly varying tails, our multivariate folding allows for the estimation of the spectral probability measure. A new weakly consistent estimator based on the classical empirical estimator is proposed. Its behaviour is illustrated through simulations and an actuarial application relative to reinsurance pricing in the case of an insurance data-set.

JØRGENSEN, PETER LØCHTE; GATZERT, NADINE. *On risk charges and shadow account options in pension funds.* 616–639. This paper studies the economic implications of regulatory systems which allow equityholders of pension companies to not only charge a specific premium to compensate them for their higher risk (compared to policyholders), but also to accumulate these risk charges in a so-called shadow account in years when they are not immediately payable due to e.g. poor investment results. When surpluses are subsequently reestablished, clearance of the shadow account balance takes priority over bonus/participation transfers to policyholders. We see such a regulatory accounting rule as a valuable option to equityholders and our paper develops a model in which the influence of risk charges and shadow account options on stakeholders' value can be quantified and studied. Our numerical results show that the value of shadow account options can be significant and thus come at the risk of expropriating policyholder wealth. However, our analysis also shows that this risk can be remedied if proper attention is given to the specific contract design and to the fixing of fair contract parameters at the outset.

ZHU, JINXIA. *Dividend optimization for general diffusions with restricted dividend payment rates.* 592–615. The dividend optimization problem is studied for a surplus process modeled by a general diffusion where both the drift and diffusion coefficients are functions of the surplus. The dividend payment rate is restricted. The objective is to find an optimal strategy that maximizes the total expected discounted dividends until ruin. It is shown that an optimal strategy is to pay no dividends when the surplus is below a threshold [b*] and to pay out dividends at the maximal possible rate when the surplus reaches or is above the threshold [b*]. We also give a result on how to determine [b*] and the value function and derive some analytical properties of the value function.

BUCHARDT, KRISTIAN; MØLLER, THOMAS; SCHMIDT, KRISTIAN BJERRE. *Cash flows and policyholder behaviour in the semi-Markov life insurance setup.* 660–688. Within the setup of a semi-Markov process in a finite state space, we consider a life insurance contract. First, without the

modelling of policyholder behaviour, we show how to calculate the expected cash flow associated with future payments, and to that end we present a version of Kolmogorov's forward integro-differential equation. The semi-Markov model is then extended to include modelling of surrender and free policy behaviour, and the main result is a modification of Kolmogorov's forward integro-differential equation, such that the cash flow can be calculated without significantly more complexity than the cash flow without policyholder modelling. The result is also demonstrated for the traditional Markov case where there is no duration dependence, and numerical examples are studied.

LEMOINE, KILLIAN. *Mortality regimes and longevity risk in a life annuity portfolio*. 689–724. This paper explores the presence of changes of trends or jumps in French mortality from 1947 to 2007, and assesses their implications on the longevity risk management of a life annuity portfolio. We accomplish this by extending the Poisson log-bilinear regression developed by Brouhns et al. (2002) [Brouhns, N, Denuit, M and Vermunt, J (2002). A Poisson log-bilinear regression approach to the construction of projected lifetables. Insurance: Mathematics and Economics 31(3), 373–393] with a regime-switching model. Estimation results show that French mortality is characterized by two distinct regimes. One refers to a strong uncertainty state, which corresponds to the longevity conditions observed during the decade following World War II. The second regime is related to the low volatility of longevity improvements observed during the last 30 years. We use these results to analyze the impact of mortality regimes on the longevity risk management of a life annuity portfolio. Simulation results suggest that the changes of trends in the mortality process have some implications for longevity risk management.

YANG, YANG; KONSTANTINIDES, DIMITRIOS G. *Asymptotics for ruin probabilities in a discrete-time risk model with dependent financial and insurance risks*. 641–659. Let us consider a discrete-time insurance risk model with insurance and financial risks, where the insurance net loss within period [i] and the stochastic discount factor over the interval [(i 1, i] follow a certain dependence structure for each fixed [i > 1]. Under the assumption that the distribution of net insurance loss within one time period is consistently varying-tailed, precise estimates for finite and infinite time ruin probabilities are derived. Furthermore, these estimates are uniform on the time horizon.

YI, BO; VIENS, FREDERI G; LI, ZHONGFEI; ZENG, YAN. *Robust optimal strategies for an insurer with reinsurance and investment under benchmark and mean-variance criteria*. 725–751. In this paper, an ambiguity-averse insurer (AAI) whose surplus process is approximated by a Brownian motion with drift, hopes to manage risk by both investing in a Black-Scholes financial market and transferring some risk to a reinsurer, but worries about uncertainty in model parameters. She chooses to find investment and reinsurance strategies that are robust with respect to this uncertainty, and to optimize her decisions in a mean-variance framework. By the stochastic dynamic programming approach, we derive closed-form expressions for a robust optimal benchmark strategy and its corresponding value function, in the sense of viscosity solutions, which allows us to find a mean-variance efficient strategy and the efficient frontier. Furthermore, economic implications are analyzed via numerical examples. In particular, our conclusion in the mean-variance framework differs qualitatively, for certain parameter ranges, with model-uncertainty robustness conclusions in the framework of utility functions: model uncertainty does not always result in an agent deciding to reduce risk exposure under mean-variance criteria, opposite to the conclusions for utility functions in Maenhout [Maenhout, P. J. (2004). Robust portfolio rules and asset pricing. The Review of Financial Studies 17: 951–983; Maenhout, P. J. (2006). Robust portfolio rules and detection-error probabilities for a mean-reverting risk premium. Journal of Economic Theory 128: 136–163] and Liu [Liu, H. N. (2010). Robust

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consumption and portfolio choice for time varying investment opportunities. Annals of Finance 6: 435–454]. Our conclusion can be interpreted as saying that the mean-variance problem for the AAI explains certain counter-intuitive investor behaviors, by which the attitude to risk exposure, for an AAI facing model uncertainty, depends on positive past experience.

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Variance

8(2), 2014

AGBEKO, TONY; HIABU, MUNIR; MARTÍNEZ MIRANDA, MARÍA DOLORES; NIELSEN, JENS PERCH; VERRALL, RICHARD J. *Validating the double chain ladder stochastic claims reserving model.* 138–160. Double chain ladder, introduced by Martínez-Miranda et al. (2012) [Martínez Miranda, María Dolores; Nielsen, Jens Perch; Verrall, Richard J (2012). Double chain ladder, ASTIN Bulletin (2012) 42(1): 59–76], is a statistical model to predict outstanding claim reserve. Double chain ladder and Bornhuetter-Ferguson are extensions of the originally described double chain ladder model which gain more stability through including expert knowledge via an incurred claim amounts triangle. In this paper, we introduce a third method, the incurred double chain ladder, which replicates the popular results from the classical chain ladder on incurred data. We will compare and validate these three using two data sets from major property and casualty insurers.

EVANS, JONATHAN P; DEAN, CURTIS GARY. *The optimal number of quantiles for predictive performance testing of the NCCI experience rating plan.* 89–104. Quantile testing is a key technique for fitting parameters and testing performance in workers compensation experience rating and the number of quantile intervals must be specified for such a test. A model is developed to compare the error in the quantile test empirical estimates of relative pure loss ratios to the interquantile differences between expected pure loss ratios. Theoretical model predictions are compared to empirical results from bootstrap quintile tests of the National Council on Compensation Insurance (NCCI) Experience Rating Plan (ERP). The model predicts that the noise-to-signal ratio grows in proportion to the 1.5 power of the number of quantiles and in inverse proportion to the 0.5 power of the sample size of risks. Empirical quintile and decile tests of NCCI's Experience Rating Plan are consistent with model predictions. Increasing the number of quantiles requires a much greater proportional increase in data volume to maintain a constant noise- to-signal ratio. This explains the use of few quantiles, specifically quintiles, for testing NCCI's Experience Rating Plan.

LEONG, WENG KAH; WANG, SHAUN S; CHEN, HAN. *Back-testing the ODP bootstrap of the paid chain-ladder model with actual historical claims data.* 182–202. This paper back-tests the popular over-dispersed Poisson bootstrap of the paid chain-ladder model from England and Verrall(2002) [England, P and Verrall, R (2002), Stochastic claims reserving in general insurance, British Actuarial Journal 8(3): 443–518], using data from hundreds of U.S. companies, spanning three decades. The results show that the modeled distributions underestimate reserve risk. We investigate why this may occur, and propose two methods to increase the variability of the

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distribution to pass the back-test. In the first method, we use a set of benchmark systemic risk distributions. In the second method, we show how to apply a Wang transform to estimate the systemic bias of the chain-ladder method over the course of the underwriting cycle.

WENDLING, THOMAS EMIL. *Actuarial portfolio management of infrastructure service contracts.* 161–180. A firm will replace a physical asset at the end of its useful life. This fact demonstrates that there is a notion of mortality implicit in the way an enterprise manages its physical assets. We propose a theory that there is also an efficient time to replace a physical asset that is random and observable. Separate economic and financial models converge on agreement that (1) there is only one instant in time that an asset must be replaced in order to minimize the present value cost impact to the enterprise; (2) that this efficient instant is observable, and a function of both the enterprise's cost of capital and readily obtainable current calendar year information; and (3) that the time to this efficient instant is random, and may be infinite. Through a policy of coordinating the timing of replacements with these efficient, observable instants, lost efficiencies are recovered. Such a policy necessarily creates volatile, fortuitous, future cash flows, which are dealt with through capital adequacy or risk transfer, rather than deferral or other forms of scheduling for convenience. The efficiency gains and accompanying value creation may be material if the enterprise's assets are mostly physical. The potential role of the extended service contract to implement such a policy, and to transfer the resulting uncertain cash flows between entities, is reviewed. A broad comparison to prior capital expenditure planning methods is made. Possible tax consequences due to the interaction between efficiency and fortuity are discussed.

YAMASHIRO, MARCUS M. *Recursive credibility: using credibility to blend reserve assumptions.* 105–137. When estimating loss reserves, actuaries usually give varying weights to multiple indications to arrive at their final selected indication. The common practice is to give weight to indications that have been developed to their ultimate expected amount. Alternatively, weight could be given to each recursive indication of paid and incurred losses, essentially averaging assumptions iteratively rather than waiting until the final estimate before selecting weights. The Munich chain ladder (MCL) is closely related to such an approach; in fact, each of the paid and incurred estimates is essentially equivalent to the recursively weighted sum of two indications, the chain ladder and a second indication, coined in this paper, the "cross link." However, the Munich chain ladder can at times be unstable, so a different approach may be more appropriate. The framework described in this paper is a direct recursive credibility approach. By contemplating the variance of credibility weights themselves, it is an improvement in stability compared to the MCL. It also offers the possibility of recursive application of credibility to other pairs of model assumptions, and it may be generalizable to more than two pairs of assumptions.