Actuarial and Financial Mathematics Conference

Interplay between Finance and Insurance

06-07 February 2020

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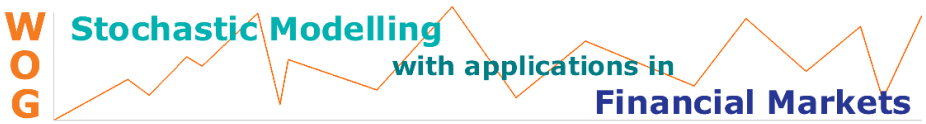

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Lunches and coffee breaks : Marble room

Conference dinner : University foundation (Egmontstraat 11, 1000 Brussel)

Map with important locations : available on

http://www.afmathconf.ugent.be/index.php?page=practicalinfo

Wireless internet

There is wireless internet available in the main building and throne building.

- SSID = academie.
- This is an open network, no password is needed.

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10h15 – 10h45	CONTRIBUTED TALK - Christian Furrer, University of Copenhagen / PFA Pension, Denmark **Tax- and expense-modified risk-minimization for insurance payment processes**
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14h45 - 15h15	CONTRIBUTED TALK - Martin Bladt, University of Lausanne, Switzerland **Matrix Mittag–Leffler distributions and modeling heavy-tailed risks**
15h15 - 15h45	CONTRIBUTED TALK - Francesco Ungolo, Technology University of Eindhoven, Netherlands **A Hierarchical Model for the Joint Mortality Analysis of Pension Scheme Data With Missing Covariates**
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	Chair: Michel Vellekoop
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09h45 - 10h15	CONTRIBUTED TALK - Florian Bourgey, Ecole Polytechnique, France **Meta-model of a large credit risk portfolio in the Gaussian copula model**
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11h30 - 12h00	CONTRIBUTED TALK - Paolo Gambetti, UCLouvain, Belgium **Forecasting recovery rates on non-performing loans with machine learning**
12h00 – 13h00	Sandwich lunch combined with **Poster session**
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13h45 - 14h15	CONTRIBUTED TALK - Nathan Lassance, UCLouvain, Belgium **Portfolio selection: A target-distribution approach**
14h15 - 14h45	Coffee break
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  Predictive Claim Scores for Dynamic Multi-Product Risk Classification in Insurance

ABSTRACTS – Presentations – 6 February

Insurance Pricing in a Competitive Market

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Insurance is usually defined as "*the contribution of the many to the misfortune of the few*". This idea of pooling risks together using the law of large number legitimates the use of the expected value as actuarial "fair" premium. In the context of heterogeneous risks, nevertheless, it is possible to legitimate price segmentation based on observable characteristics. But in the context of "Big Data", intensive segmentation can be observed, with a much wider range of offered premium, on a given portfolio. In this talk, we will briefly get back on economical, actuarial and philosophical approaches of insurance pricing, trying to link a fair unique premium on a given population and a highly segmented one. We will then get back on recent experiments (so-called "actuarial pricing game") organized since 2015, where (real) actuaries were playing in competitive (artificial) market, that mimic real insurance market. We will get back on conclusions obtained on two editions, the first one, and the most recent one, where a dynamic version of the game was launched.

Tax- and expense-modified risk-minimization for insurance payment processes

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Joint work with: K. Buchardt and T. Moller

We study the problem of determining risk-minimizing investment strategies for insurance payment processes in the presence of taxes and expenses. We consider the situation where taxes and expenses are paid continuously and symmetrically and introduce the concept of tax- and expense-modified risk-minimization. Risk-minimizing strategies in the presence of taxes and expenses are derived and linked to Galtchouk-Kunita-Watanabe decompositions associated with modified versions of the original payment processes. Furthermore, we show equivalence to an alternative approach involving an artificial market consisting of after-tax and after-expense assets, and we establish a type of consistency with classic risk-minimization. Finally, a case study involving classic multi-state life insurance payments in combination with a bond market exemplifies the results.

A novel multi-elliptical family of distributions: definitions, properties and risk capital decomposition

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Joint work with: Tomer Shushi

The multivariate elliptical family of distributions is well studied and commonly used in actuarial science and finance. However, it has an essential shortcoming: all its univariate marginal distributions are the same, up to location and scale transformations. This happens because these marginal distributions have the same density and characteristic generators. For example, all marginals of the multivariate Student-t distribution, an important member of the elliptical class, have the same number of degree of freedoms. We introduce a generalisation of the multivariate elliptical family of distributions that considers marginals with different density generators. This becomes important when dealing with insurance and financial data. We further provide the main characteristics of the multi-elliptical family of distributions: characteristic and density functions, expectations, and covariance matrices. Furthermore, we derive important risk measures for the introduced distributions, such as the value at risk (VaR) and tail conditional expectation (TCE). We also provide the TCE-based capital allocation of aggregate risks.

Quasi-Monte Carlo for multivariate distributions via generative neural networks

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Joint work with: A. Prasad, M. Zhu

A novel approach based on generative neural networks is introduced for constructing quasi-random number generators for multivariate models with any underlying copula in order to estimate expectations with variance reduction. So far, quasi-random number generators for multivariate distributions required a careful design, exploiting specific properties (such as conditional distributions) of the implied copula or the underlying quasi-Monte Carlo point set, and were only tractable for a small number of models. Utilizing specific generative neural networks allows one to construct quasi-random number generators for a much larger variety of multivariate distributions without such restrictions. Once trained with a pseudo-random sample, these neural networks only require a multivariate standard uniform randomized quasi-Monte Carlo point set as input and are thus fast in estimating expectations under dependence with variance reduction. Reproducible numerical examples are considered to demonstrate the approach. Emphasis is put on ideas rather than mathematical proofs.

Matrix Mittag–Leffler distributions and modeling heavy-tailed risks

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Joint work with: H. Albrecher, M. Bladt

In this paper we define the class of matrix Mittag-Leffler distributions and study some of its properties. We show that it can be interpreted as a particular case of an inhomogeneous phase-type distribution with random scaling factor. We then identify this class and its power transforms as a remarkably parsimonious and versatile family for the modelling of heavy-tailed risks, which overcomes some disadvantages of other approaches like the problem of threshold selection in extreme value theory. We illustrate this point both on simulated data as well as on a set of real-life MTPL insurance data that were modeled differently in the past.

A Hierarchical Model for the Joint Mortality Analysis of Pension Scheme Data With Missing Covariates

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Joint work with: T. Kleinow, A.S. Macdonald

A hierarchical model is developed for the joint mortality analysis of pension scheme populations. It generalizes the proportional hazards framework when accounting for covariates. In this work we consider parameter uncertainty using Bayesian techniques. Model parametrization is analysed in order to obtain an effcient MCMC sampler, and the model selection issue is addressed. The inferential framework described in this work accommodates for any missing data pattern, and turns out to be useful to analyse the statistical relationship among covariates. Finally, we assess the financial impact of using the covariates, and of the optimal use of the whole available sample when combining different
mortality experiences for the estimation of mortality rates.

Intergenerational risk sharing in DC pension plan with minimum pension guarantee

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Joint work with: C. Hillairet (CREST, ENSAE) and M. Mrad (LAGA, Univ. Paris 13)

Intergenerational solidarity is one of the main pillars of pay-as-you-go (PAYG) pension plans. In (unfunded) PAYG systems, contributions paid by working participants are redistributed to current retirees, inducing risk sharing between generations. However, PAYG systems in aging countries face serious challenges caused by both decrease in birth rates and an unprecedented increase in the duration of life. In this context, the sustainability of Defined Benefits (DB) PAYG systems has become a key challenge for policymakers, while Defined Contribution (DC) plans have gained momentum in the past years. However, DC PAYG pension systems should provide adequate benefits for retirees. In summary, an adverse demographic profile makes DB plans potentially unsustainable, while DC systems may reduce lifelong benefits.

In this paper, we study the redistribution properties of a PAYG system where defined contributions are combined with a minimum pension guarantee, and the social planner can invest part of the contributions (or borrow) in a buffer fund, operating as a risk-sharing mechanism among generations.

We propose and study the existence of an *adaptative* optimal policy design under sustainability and adequacy constraints. An important point is to convey the complexity of the problem, by taking into account key phenomena such as the demographic risk and its evolution over time, the time and age dependence of agents preferences, or financial risks. We consider a dynamic and continuous time framework, which incorporates the heterogeneity of overlapping generations and its evolution over time. Finally, we study the actuarial fairness of the optimal policy design for different generations, under several demographic and financial scenarios.

A fresh look on the linkage of model uncertainty and validation

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The scene is set by summarizing important criteria for validation. The focus will be on the current state of affairs, how model uncertainties should be treated and managed. We deep dive into practical examples about model uncertainties related to the Monte-Carlo-sample size, how regulators treat model uncertainty for life models and how model uncertainties may be treated within operational risk. Furthermore, a methodological focus is on the application related to the uncertainties stemming from the specification of a particular copula function. Last but not least, it will be shown that also the standard formula of Solvency II is prone to model uncertainty.

ABSTRACTS – Presentations – 7 February

Deep XVA analysis

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Since the 2008-09 financial crisis, derivative dealers charge to their clients various add-ons, dubbed XVAs, meant to account for counterparty risk and its capital and funding implications for banks. Two competing XVA paradigms are a replication framework and a cost-of-capital, incomplete market approach. Burgard and Kjaer once dismissed an earlier incarnation of the Albanese and Crépey holistic, incomplete market XVA model as being elegant but difficult to solve explicitly. In this talk we show that this model, set on a forward/backward SDE formulation, is not only well-grounded economically, but also able to be solved efficiently using GPU computing combined with machine learning methods in a whole bank balance sheet context. We calculate the mark-to-market cube using GPU computing, and the XVAs, as well as the embedded initial margin and economic capital processes, using deep learning regression and quantile regression schemes.

Meta-model of a large credit risk portfolio in the Gaussian copula model

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Joint work with: Emmanuel Gobet - Clément Rey

We design a meta-model for the loss distribution of a large credit portfolio in the Gaussian copula model. Using both the Wiener chaos expansion on the systemic economic factor and a Gaussian approximation on the associated truncated loss, we significantly reduce the computational time needed for sampling the loss and therefore estimating risk measures on the loss distribution.
The accuracy of our method is confirmed by many numerical examples.

Deep neural network approximations to high-dimensional control and games in finance

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Joint work with: Yufei Zhang

In this talk, we discuss the feasibility of algorithms based on deep artificial neural networks (DNN) for the solution of high-dimensional stochastic control problems and zero-sum games arising in financial engineering. In the first part, we show that in certain cases the value functions can be represented by a DNN without the curse of dimensionality. In the second part, we exploit policy iteration to reduce the nonlinear problem into a sequence of linear problems, which are then further approximated via a multilayer feedforward neural network ansatz. Moreover, we construct the optimal feedback controls based on the superlinear convergence of the numerical solutions. Preliminary numerical experiments are presented to illustrate the theoretical results and to demonstrate the effectiveness of the method.

Forecasting recovery rates on non-performing loans with machine learning

Paolo Gambetti

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Joint work with: A. Bellotti, D. Brigo, F. Vrins

We compare the performances of a wide set of regression techniques and machine learning algorithms for predicting recovery rates on non-performing loans, using a private database from a European debt collection agency. We find that rule-based algorithms such as Cubist, boosted trees and random forests perform significantly better than other approaches. In addition to loan contract specificities, the predictors referring to the bank recovery process – *prior to the portfolio's sale* to the debt collector – are also proven to strongly enhance forecasting performances. These variables, derived from the time-series of contacts to defaulted clients and clients' reimbursements to the bank, help all algorithms to better identify debtors with different repayment ability and/or commitment, and in general with different recovery potential.

Low-Rank Tensor Approximation for Parametric Option Pricing

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Joint work with: Paolo Colusso, Daniel Kressner and Francesco Statti

Computationally intensive problems in finance are characterized by their intrinsic high-dimensionality which often is paired with optimizations leading to nonlinearities. While classial numerical methods typically suffer from a curse in dimensionality, machine learning approaches promise to yield fairly accurate results with a method that is scalable in the dimensions. Computational intense training phases and the required large set of training data pose some of the major challenges for the development of new and adequate numerical methods for finance. Merging classical numerical techniques with learning methods we propose a new approach to option pricing in parametric models. The work is based on [1] and ongoing research with Paolo Colusso and Francesco Statti.

Glau, K.; Kressner, D.; Statti, F.: Low-rank tensor approximation for Chebyshev interpolation in parametric option pricing. preprint 2019, arXiv:1902.04367

Portfolio selection: A target-distribution approach

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Joint work with: Frédéric Vrins

We introduce the *minimum-divergence portfolio*, a strategy that accounts for higher moments in a simple and intuitive way. It is the portfolio whose return density is as close as possible to a target-return density that captures the investor's preferences.We study target densities among the generalized-normal family, for which the objective function admits a natural decomposition. We propose to match the first two target-return moments to those of a *reference portfolio*, chosen on the mean-variance efficient frontier. The minimum-divergence portfolio is therefore expected to be close to the reference portfolio, but with higher return moments implicitly *shrunk* toward those of the target. We demonstrate that we recover Markowitz's efficient frontier when asset returns are Gaussian, and when a Dirac-delta target is taken. An extensive empirical study reveals that minimum-divergence portfolios exhibit comparable mean-variance trade-offs as the reference portfolios, but feature substantially less tail risk, including in crisis periods. Moreover, our strategy is shown to outperform common higher-moment portfolios on a wide set of benchmark datasets.

Nash Equilibria in Optimal Reinsurance Bargaining

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Joint work with: Tim J. Boonen, University of Amsterdam

We introduce a strategic behavior in reinsurance bilateral transactions, where agents choose the risk preferences they will appear to have in the transaction. Within a wide class of risk measures, we identify agents' strategic choices to a range of risk aversion coefficients. It is shown that at the strictly beneficial Nash equilibria, agents appear homogeneous with respect to their risk preferences. While the game does not cause any loss of total welfare gain, its allocation between agents is heavily affected by the agents' strategic behavior. This allocation is reflected in the reinsurance premium, while the insurance indemnity remains the same in all strictly beneficial Nash equilibria. Furthermore, the effect of agents' bargaining power vanishes through the game procedure and the agent who gets more welfare gain is the one who has an advantage in choosing the common risk aversion at the equilibrium. This work is linked to the ongoing literature on strategic risk-sharing transactions.

Near-Optimal Dynamic Asset Allocation in Financial Markets with Trading Constraints

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Joint work with: Antoon Pelsser

We develop a dual control method for approximating investment strategies in incomplete environments that emerge from the presence of market frictions. Convex duality enables the approximate technology to generate lower and upper bounds on the optimal value function. The mechanism rests on closed-form expressions pertaining to the portfolio composition, whence we are able to derive the near-optimal asset allocation explicitly. In a real financial market, we illustrate the accuracy of our approximate method on a dual CRRA utility function that characterizes the preferences of some finite-horizon investor. Negligible duality gaps and insignificant annual welfare losses substantiate accuracy of the technique.

ABSTRACTS – Posters

Risk Sharing for Public Pension Scheme

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Joint work with: Prof. Pierre Devolder

Here we study the various possible architectures for a financially sound social security system and to develop optimal form of risk sharing between/within generations. We will develop a framework to assess various reforms impact on long-term financial sustainability of pensions, with a particular attention to the role of Defined benefits (DB) vs Defined contributions (DC), and the framework of Musgrave and Convex Combination.

Covariance estimation under heteroscedasticity: estimation and accuracy via concentration inequalities

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Joint work with: E. Gobet, J.P. Lemor

Covariance matrix is a key parameter in portfolio optimization problems. Since it is not known in practice, it is estimated, usually as the sample covariance on historical returns. However, the number of data might not be sufficient to provide a reliable estimation and the sample approach might not be adapted.

Concentration inequalities are statistical tools whose aim is to quantify the statistical fluctuation of an empirical estimator around its mean. They provide majoration on the error level probability explicit in the number of variables. In this poster, we quantify the sample covariance estimation error via concentration inequalities techniques.

In a second part, we consider investments of fixed allocation during a holding period. We propose to consider as covariance matrix the expected realized variance over the holding period estimated at the investment day. Under the GARCH-CCC model, explicit formula can be obtained. Results from matrix concentration inequality (see Tropp, 2011) and optimization sensitivity analysis (Bonnans and Shapiro, 2000) can be adapted to study the fluctuations of the portfolios realized variance and weights. Empirical illustration for the minimum variance portfolio shows that the proposed covariance estimation gives lower realized variance than the sample covariance for investment period of the same order of magnitude than the GARCH half-life time.

Sensitivity analysis with chi-square divergences

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Joint work with: Andreas Tsanakas, Pietro Millossovich

We introduce an approach to sensitivity analysis for quantitative risk models, such as those used in solvency calculations. The aim of the sensitivity analysis method is to identify the most influential – and hence most important – inputs of a model. The approach follows two steps:

- A change of measure is used as a tool to re-weight different scenarios (states of the world). The Radon-Nikodym density is derived by minimizing the chi-square divergence under a constraint (stress) on the expectation of a chosen random variable (model input or output).

- The change of measure is used to produce a stress on the distribution of any variable of interest. The distortion in the empirical distribution of the model inputs and output are quantified.

We give an explicit solution to the divergence minimization problem, which yields a Radon-Nikodym density that is a piecewise linear function of the random variable whose expectation is being stressed. The sensitivity analysis method is illustrated through a numerical example of a simple insurance portfolio. We follow two distinct approaches: in the first we stress the expectation of the output and monitor the distribution of the inputs; in the second, we stress the expectation of all inputs in turn, and evaluate the change in (risk measures of) the output.

The approach taken in this paper gives an applicable alternative to common sensitivity analysis methods used in the insurance industry: as it provides a consistent manner of stressing risk factors and only requires a single set of simulated input/output scenarios, resulting in easy implementation.

One-year premium risk and emergence pattern of ultimate loss based on conditional distribution

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Joint work with: Ł. Delong

In non-life insurance we model the cumulative payments $(X_1, X_2, ..., X_n)$ associated with a given accident year, where X_i denotes the claims paid up to the i-th development year. We consider premium risk for planned earned premiums. Due to Solvency II requirements which focus on the one-year perspective of the ultimate loss, it is important to model the volatility of the best estimate of the ultimate loss given by $BE_1 = \mathbb{E}[X_n|X_1]$. We follow the approach discussed in [1] and [2] who introduce the concept of emergence patterns, which allow us to simulate BE_1 starting from X_n. The authors suggest that the ultimate loss X_n can be mapped into the best estimate of the ultimate loss BE_1 by using a simple linear function. We derive the conditional distributions of $BE_1|X_n$ in non-life actuarial models commonly used in claims reserving and postulate new non-linear emergence pattern formulas. We study Gaussian Incremental Loss Ratio model, Hertig's lognormal model and Over-Dispersed Poisson model. We investigate standard deviations and Value-at-Risk measures in the one-year loss model and the ultimate loss model, and the relations between them.

References

[1] Bird. C., Cairns, M. (2011), "Practical experiences of modelling one-year risk emergence." *GIRO Conference and Exhibition 2011*.

[2] England, P., Cairns, M., Scarth, R. (2012), "The 1 year view of reserving risk: The "actuary-in-the-box" vs emergence patterns. " *GIRO Conference and Exhibition 2012*.

[3] Delong, Ł., Szatkowski, M. (2019), "One-year premium risk and emergence pattern of ultimate loss based on conditional distribution. " *Working paper*.

Pricing American Option Using The Monte Carlo-Tree (MC-Tree) Method.

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Joint work with: Bernard HANZON, Head of Department of Mathematics, University College Cork.

The binomial tree model and the Monte Carlo simulation are popular methods for solving option pricing problems. The purpose of this paper is to introduce a pricing method, Monte Carlo-Tree (MC-Tree), which is a combination of the Monte Carlo method and a tree method to approximate the price of American options with the requirement of high accuracy. There are no known analytical solutions for general American options in a closed and simple form. In this presentation, we compare the MC-Tree method with other numerical methods such as Cox, Ross Rubenstein (CRR), and Jarrow-Rudd (JR), as well as Longstaff-Schwartz Method(LSM). We also compare with the "true" price, where the "true" price of an American put option is obtained by the convergent binomial method with the depth of tree at 50,000. Besides, we compare the mean and the standard deviation of the results of simulations when comparing MC-Tree with LSM. Considering our simulation results, MC-Tree brought more accuracy, compared with other numerical methods, although it is still costly in computation. It is noticeable that the MC-Tree method is more accurate than the LSM at the same computational cost. The MC-Tree method needs a fewer number of simulations than LSM to obtain a given level of accuracy, resulting in a decrease in computation time of the MC-Tree method. The MC-Tree method performs better than other methods: CRR, JR in terms of accuracy, using the same tree depth.

One benefit of the MC-tree approach is that it allows us to work with the confidence interval of the MC simulation. If we use only the tree method, we can not have the confidence interval and its benefit. The confidence interval depends on the number of simulations. We find that if we fix the computation time, there is an optimal choice of tree depth N and the number of Monte Carlo simulations M, where N and M are both larger than one. We find N and M in the relation $M = \frac{C}{N(N+1)}$, where C is chosen approximately.

The MC-Tree model opens up to the option of dealing with multi-asset option, based on the tree construction in the paper by Sierag and Hanzon. The maximal depth of the tree used in that case is expected to be limited due to computational constraints for the multi-asset case. In addition, we are interested in Credit Value Adjustment (CVA), and American option type calculations form part of CVA calculations. Future direction for improvement on MC-Tree method is finding methods to decrease the computational effort as well as developing the theory in the multi-dimensional case. We are presently experimenting with using a special chip (a field-programmable gate array (FPGA)) to do fast tree computations. The FPGA is expected to speed up the computation at the deepest hardware level. The FPGA implementation helps to reduce the computation time of the MC-Tree method in higher-dimensional case.

Predictive Claim Scores for Dynamic Multi-Product Risk Classification in Insurance

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It has become standard practice in the non-life insurance industry to employ Generalized Linear Models (GLMs) for insurance pricing. However, these GLMs traditionally work only with *a priori* characteristics of policyholders, while nowadays we increasingly have *a posteriori* information of individual customers available, sometimes even across multiple product categories. In this paper, we therefore consider a dynamic claim score to capture this *a posteriori* information over several product lines. More specifically, we extend the Bonus-Malus-panel model of Boucher and Inoussa (2014) and Boucher and Pigeon (2018) to include claim scores from other product categories and to allow for non-linear effects of these scores. The application of the resulting multi-product framework to a Dutch property and casualty insurance portfolio shows that the claims experience of individual customers can have a significant impact on the risk classification and that it can be very profitable to account for it.

Keywords: Multi-product risk profiles, dynamic claim score, Bonus-Malus Systems, Generalized Additive Models, cross-selling potential, insurance pricing.

References

[1] Boucher, J.-P. and Inoussa, R. (2014). A posteriori ratemaking with panel data. *ASTIN Bulletin*, 44(3):587–612.

[2] Boucher, J.-P. and Pigeon, M. (2018). A claim score for dynamic claim counts modeling. Retrieved from `arxiv.org/abs/1812.06157`

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