INNOVATIONS IN INSURANCE, RISK- & ASSET MANAGEMENT

APRIL 05 – 07, 2017 CONFERENCE AT THE TECHNICAL UNIVERSITY OF MUNICH





Chair of Mathematical Finance

SUPPORTED BY





Innovations in Insurance, Risk- and Asset Management Munich, April 5 – 7, 2017

Insurance companies and banks alike have to handle difficult market circumstances, face massive regulatory requirements (Solvency II and Basel 4), and have to compete and collaborate with FinTech start-ups in times of a new digital revolution. Today's insurance markets are very competitive, another consequence of the ongoing digitalization, the result being eroding profits and an industry wide aggregation process. Low interest rates – already prevailing for a remarkable period – challenge traditional asset management habits and change customers' needs with respect to long-term savings. This aggregated pressure compels the need for innovative ideas and thorough investigations.

Our conference provides time and venue, as well as distinguished presenters, for innovations nourished from the needs of the financial industry and new developments in the interdisciplinary scientific field of mathematical finance, actuarial science, and quantitative risk management. In particular, we are dedicated to bring together practitioners from insurance, banking, risk- and asset management with academics conducting research in this field. Thematically, we focus on the mathematics of extreme risks, systemic risk, model uncertainty, big data / data science, interest rate and hybrid models, alternative investments, dynamic investment strategies, quantitative risk management, asset liability management, liability driven investments, and behavioral finance.

Scientific Organizers

K. Glau, D. Linders, A. Min, M. Scherer, L. Schneider and R. Zagst

Local Organizers

B. Haas, M. Mahlstedt, C. Pötz and A. Wenninger

Website

https://www.mathfinance.ma.tum.de/konferenz-2017/

Welcome

Dear guests,

We are delighted to welcome you to the conference "Innovations in Insurance, Risk-& Asset Management" at the Technical University of Munich. This conference is part of an initiative called "KPMG Center of Excellence in Risk Management" (KPMG CE) that was founded in 2012 as a cooperation between the Chair of Mathematical Finance at the Technical University of Munich and KPMG AG Wirtschaftsprüfungsgesellschaft.

This cooperation is based on three pillars: first strengthening a scientifically challenging education of students that at the same time addresses real world topics, second supporting research with particular focus on young researchers, and third, bringing together academic researchers with practitioners from the financial industry in order to develop trend-setting and viable improvements in the effective management of financial risks. The aim of this conference is to provide a venue for practitioners and academics involved in the area of risk modeling for insurance companies, banks, and asset managers, to present state-of-the-art research, exchange ideas, and share visions on future developments in these fields. Looking into this book of abstracts, we are certain that this aim will be met as this includes manifold exciting topics, from developments in financial theory, new applications to actuarial and capital models to practical trends and challenges in risk management.

We would like to thank everyone who contributes to this event, the scientific committee, the organizational team, the speakers, and all participants. In particular, we express our gratitude to Prof. Rudi Zagst and Prof. Matthias Scherer who made this third large KPMG CE conference possible.

We wish everyone a great time during the conference and are looking forward to three days with insightful talks and fruitful discussions.

Dr. Matthias Mayer, KPMG AG Wirtschaftsprüfungsgesellschaft Dr. Daniel Sommer, KPMG AG Wirtschaftsprüfungsgesellschaft Franz Lorenz, KPMG AG Wirtschaftsprüfungsgesellschaft

Scientific Committee



Kathrin Glau Chair of Mathematical Finance Technical University of Munich



Daniël Linders Chair of Mathematical Finance Technical University of Munich



Aleksey Min Chair of Mathematical Finance Technical University of Munich

Scientific Committee



Matthias Scherer Chair of Mathematical Finance Technical University of Munich



Lorenz Schneider Visiting Professor KPMG Center of Excellence in Risk Management Technical University of Munich



Rudi Zagst Chair of Mathematical Finance Technical University of Munich

Program

Wednesday

Wednesday, 5. April 2017						
8.30		Registration				
8.45 - 9.00		Welcome Address				
9.00 - 9.45		Keyn	ote 1: Hansjoerg Albr	echer		
9.50 - 10.35		Practitioner 1: Christian Bluhm				
10.35 - 11.00		Coffee Break				
11.00 - 11.45		Keynote 2: Daniel Bauer				
11.50 - 12.15	l1: W. Farkas	11.50 - 12.15	I2: N. Bäuerle	11.50 - 12.15	13: M. Fornasier	
12.20 - 12.45	14: T. Meyer-Brandis	12.20 - 12.45	15: P. Hieber	12.20 - 12.45	16: J. Mai	
12.50 - 14.00		Lunch				
14.00 - 14.45		Keynote 3: Stéphane Loisel				
14.50 - 15.35		Keynote 4: Giovanni Puccetti				
15.35 - 16.00		Coffee Break				
16.00 - 16.20	C1: M. Bissiri	16.00 - 16.20	C2: C. Ewald	16.00 - 16.20	C3: H. Fink	
16.25 - 16.45	C4: B. Karageyik	16.25 - 16.45	C5: S. Sahin	16.25 - 16.45	C6: D. Kraus	
16.50 - 17.10	C7: S. Geissel	16.50 - 17.10	C8: F. Cesarone	16.50 - 17.10	C9: T. Nagler	
17.15 - 18.00	Keynote 5: David Saunders					
18.30		Dinner (Alm)				

Program

Thursday

Thursday, 6. April 2017						
8.45 - 9.00	Welcome Address					
9.00 - 9.45		Keynote 6: Damiano Brigo				
9.50 - 10.35		Pra	ctitioner 2: Frank Sch	iller		
10.35 - 11.00		Coffee Break				
11.00 - 11.45	Keynote 7: Ralf Korn					
11.50 - 12.15	17: S. Weber	11.50 - 12.15	18: P. Bertrand	11.50 - 12.15	19: F. Biagini	
12.20 - 12.45	110: P. Ott	12.20 - 12.45	I11: M. Jeanblanc	12.20 - 12.45	I12: C. Czado	
12.50 - 14.00		Lunch				
14.00 - 14.45		Keynote 8: Alfred Müller				
14.50 - 15.35		Keynote 9: Steven Kou				
15.35 - 16.00	Coffee Break					
16.00 - 16.20	C10: E. Nevruz	16.00 - 16.20	C11: M. Mahlstedt	16.00 - 16.20	C12: L. Schneider	
16.25 - 16.45	C13: C. Piat	16.25 - 16.45	C14: C. Necula	16.25 - 16.45	C15: Di Lascio	
16.50 - 17.10	C16: E. Lütkebohme	16.50 - 17.10	C17: F.Vrins	16.50 - 17.10	C18: M. Preischl	
17.15 - 18.00	Keynote 10: Bruno Remillard					
18.30	Social Event					

Program

Friday

Friday, 7. April 2017						
8.45 - 9.00	Welcome Address					
9.00 - 9.45	Keynote 11: Josef Teichmann					
9.50 - 10.35		Practitioner 3: Iain Clark				
10.35 - 11.00	Coffee Break					
11.00 - 11.45	Practitioner 4: Bernhard Kaufmann					
11.50 - 12.15	113: E. Eberlein	11.50 - 12.15	I14: C. Bernard	11.50 - 12.15	I15: M. Keller-R.	
12.20 - 12.45	I16: S. Cohen	12.20 - 12.45	I17: R. Werner	12.20 - 12.45	l18: L. Seco	
12.50 - 14.00	Lunch					
14.00 - 14.45	Keynote 12: Johanna G. Nešlehová					
14.50 - 15.10	C19: A. Pallavicini	14.50 - 15.10	C20: S. Thonhauser	14.50 - 15.10	C21: N. Pede	
15.15 - 15.35	C22: P. Schenk	15.15 - 15.35	C23: T. Bienek	15.15 - 15.35	C24: M.Wahl	
15.40 - 16.00	C25: K. Jung	15.40 - 16.00	C26: M. Grigorova	15.40 - 16.00	C27: A. Hüttner	
16.05 - 16.30	Coffee Break					
16.30 - 17.15	Keynote 13: Damir Filipović					
17.20	Closing Remarks					

Conference Dinner



Photograph: Schloßwirtschaft Oberschleißheim

Date: Wednesday, 05.04.2017

Place: "Alm", Schloßwirtschaft Schleißheim

Dinner: Three-course menu (a vegetarian or vegan main course is locally selectable)

Price: 50 EUR including the dinner, drinks and the bus ride (ONE departure and return possibility from Parkring to Restaurant)

Social Event



Photograph: Deutsches Museum Flugwerft

Date: Thursday, 06.04.2017

Topic: Two English guided and **one German** guided tour in "Deutsches Museum Flugwerft Schleißheim"

Price: The guided tour and the bus ride from Parkring is for free

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Key-Note Speakers

On the Optimality of Reinsurance Forms

Hansjörg Albrecher, HEC Lausanne

Reinsurance is an important ingredient in the risk management of insurance companies. Over the last decades there has been an enormous academic activity on identifying optimal reinsurance forms under given objectives and constraints. At the same time, this developed expertise sometimes has limited applicability in practice where additional factors and constraints play a role that are sometimes difficult to formalize. In this talk some recent developments in trying to narrow the gap between academic research and practical viewpoints on the topic will be discussed, with a particular emphasis on the role of capital. This will also lead to the identification of the potential attractiveness of some non-standard reinsurance forms.

A Least-Squares Monte Carlo Approach to the Calculation of Capital Requirements

Hongjun Ha, Saint Joseph's University Daniel Bauer, Georgia State University

The calculation of capital requirements for financial institutions usually entails a reevaluation of the company's assets and liabilities at some future point in time for a (large) number of stochastic forecasts of economic and firm-specific variables. The complexity of this *nested valuation problem* leads many companies to struggle with the implementation.

Relying on a well-known method for pricing non-European derivatives, the presentation discusses and analyzes a novel approach to this computational problem based on least-squares regression and Monte Carlo simulations. We study convergence of the algorithm and analyze the resulting estimate for practically important risk measures. Moreover, we address the problem of how to choose the regressors, and show that an *optimal* choice is given by the left singular functions of the corresponding valuation operator. Numerical examples demonstrate that the algorithm can produce accurate results at relatively low computational costs, particularly when relying on the optimal basis functions.

Consistent Iterated Simulation of Multi-Variate Defaults: Markovian Indicators Characterization and Marshall Olkin Law

Damiano Brigo, Imperial College London Jan-Frederik Mai, XAIA Investment Matthias Scherer, Technische Universität München

We investigate under which conditions a single simulation of joint default times at a final time horizon can be decomposed into a set of simulations of joint defaults on subsequent adjacent sub-periods leading to that final horizon. Besides the theoretical interest, this is also a practical problem as part of the industry has been working under the misleading assumption that the two approaches are equivalent for practical purposes. We first report a partial result on joint survival of all names by Brigo and Chourdakis (2012), where it is shown that, under some very special distributions, joint terminal survival of all names is equivalent to iterated joint survival of all names in each interval up to the same final date. The distribution needed for this has exponentially distributed margins and an extreme-value or self-chaining copula as dependence structure. In particular, the Gumbel copula is the only case working in Archimedean copulas, while other copulas include the Marshall-Olkin case and Pickands functions. We next generalize the result to more general events than survival of all. As a reasonable trade-off between realistic stylized facts, practical demands, and mathematical tractability, we propose models leading to a Markovian multi-variate survival-indicator process, and we investigate two instances of static models for the vector of default times from the statistical literature that fall into this class. On the one hand, the "looping default" case is known to be equipped with this property, and we point out that it coincides with the classical "Freund distribution" in the bivariate case. On the other hand, if all sub-vectors of the survival indicator process are Markovian, as shown in Brigo, Mai and Scherer (2016) this constitutes a new characterization of the Marshall-Olkin distribution, and hence of multi-variate lack-of-memory. A paramount property of the resulting model is stability of the type of multi-variate distribution with respect to elimination or insertion of a new marginal component with marginal distribution from the same family. The practical implications of this "nested margining" property are fundamental. To implement this distribution we present an efficient and unbiased simulation algorithm based on the Levy-frailty construction. We highlight different pitfalls in the simulation of dependent default times and examine, within a numerical case study, the effect of inadequate simulation practices.

[1] Brigo D, Chourdakis K, Consistent single- and multi-step sampling of multivariate arrival times: A characterization of self-chaining copulas. Available at arXiv.org, ssrn.com, 2012.

- [2] Brigo D, Mai J.-F, Scherer M, Markov multi-variate survival indicators for default simulation as a new characterization of the Marshall-Olkin law, Statistics and Probability Letters, Volume 114, Pages 60-66, 2016.
- [3] J.-F. Mai, Multivariate exponential distributions with latent factor structure and related topics, *Habilitation thesis, Technische Universität München, https://mediatum.ub.tum.de/node?id=1236170* (2014).
- [4] J.-F. Mai, M. Scherer, Lévy-frailty copulas, *Journal of Multivariate Analysis* 100(7) (2009) pp. 1567–1585.
- [5] J.-F. Mai, M. Scherer, Reparameterizing Marshall–Olkin copulas with applications to sampling, *Journal of Statistical Computation and Simulation* 81(1) (2011) pp. 59–78.
- [6] J.-F. Mai, M. Scherer, H-extendible copulas, *Journal of Multivariate Analysis* 110 (2012) pp. 151–160.
- [7] J.-F. Mai, M. Scherer, *Simulating Copulas: Stochastic Models, Sampling Algorithms, and Applications*, Imperial College Press (2012).
- [8] J.-F. Mai, M. Scherer, What makes dependence modeling challenging? Pitfalls and ways to circumvent them, *Statistics & Risk Modeling* **30** (2013) pp. 287– 306.

Replicating Portfolio Approach to Capital Calculation

Damir Filipović, EPFL and Swiss Finance Institute Mathieu Cambou, EdgeLab

The replicating portfolio approach to the calculation of capital for life insurance portfolios is an industry standard. The replicating portfolio is obtained from projecting the terminal loss of discounted asset-liability cash flows on a set of factors generated by a family of financial instruments that can be efficiently simulated. In [1], we provide the mathematical foundations and a novel dynamic and path-dependent replicating portfolio approach for real-world and risk-neutral sampling. We show that our replicating portfolio approach yields asymptotically consistent capital estimators if the chaotic representation property holds. We illustrate the tractability of the replicating portfolio approach by two numerical examples.

 Cambou M, Filipović D, Replicating Portfolio Approach to Capital Calculation, Swiss Finance Institute Research Paper No. 16-25, 2016. Available at SSRN: https://ssrn.com/abstract=2763733.

Chance-Risk Classification of Pension Products: Scientific Concepts and Challenges

Ralf Korn, Technische Universität Kaiserslautern, Fraunhofer ITWM

Since the start of 2017, every subsidized private pension product sold in Germany needs a chance-risk classification, i.e. it needs to be assigned to a class between 1 and 5 based on simulations of the accrued wealth during the savings phase of the product. This task raises many conceptual and mathematical questions such as the choice of chance and risk measures, the choice of a capital market model, the implementation of the evolution of the customer's wealth paid into a certain product account, among others. In the talk, we will present the model that is actually used as the basis of the simulation and the classification of the products (see also [1]). We will further point out some conceptual issues such as the mapping problem of products to the basic processes, the behavior of the used interest rate model, issues of numerical methods for pricing involved derivatives.

[1] Produktinformationsstelle Altersvorsorge, Basismodell der Kapitalmarktsimulation, http://www.produktinformationsstelle.de/assets/PIA-Kapitalmarktmodell-Basisprozesse.pdf.

Exhaustible Resources with Production Adjustment Costs

Min Dai, NUS Steven Kou, NUS Cong Qin, NUS

We develop a general equilibrium model of exhaustible resources with production adjustment costs based on singular control, and show that the classical Hotelling's rule, which states that the prices of the exhaustible resources should grow at the riskfree rate, does not hold in the presence of adjustment costs; indeed, the adjustment costs can lead to a U-shaped price profile, while will significantly prolong the period of price staying at the bottom. This can help us to understand why the prices of some commodity, e.g. oil, can be quite low for a long period. In addition, our model can explain empirical phenomena observed in futures markets, such as backwardation and contango.

Quickest Detection of Change in Actuarial Assumption

Stéphane Loisel, Ecole ISFA - Université Lyon

In this talk, we present theoretical results related to optimality of the cusum strategy for quickest robust detection problem in the doubly stochastic Poisson case, under a modified Lorden criterion. We also present applications to longevity and P&C actuarial assumptions monitoring.

Expectiles, Omega Ratios and Stochastic Dominance

Alfred Müller, Universität Siegen

In the theory of risk measures *expectiles* have recently found increasing interest as they are the only risk measures that are coherent and elicitable. Comparing expectiles is mathematically equivalent to comparing *Omega ratios*, which are a well known performance measure. In this talk we explain these two concepts and investigate their relation and consistency with respect to stochastic dominance rules. In particular we introduce a new stochastic order based on expectiles that turns out to have some unexpected properties. We also give conditions under which expectiles and Omega ratios are consistent with classical first and second order stochastic dominance and

with respect to the recently introduced fractional stochastic dominance between first and second order. The talk is based on joint work with several coauthors.

- [1] Fabio Bellini, Bernhard Klar, Alfred Müller and Emanuela Rosazza Gianin (2014). Generalized quantiles as risk measures. *Insur. Math. Econ.* 54, 41-48.
- [2] Fabio Bellini, Bernhard Klar, Alfred Müller (2016). Expectiles, Omega Ratios and Stochastic Ordering. *Methodol. Comput. Appl. Probab.*, to appear.
- [3] Alfred Müller, Marco Scarsini, Ilia Tsetlin, Robert L. Winkler (2016). Between First- and Second-Order Stochastic Dominance. *Management Science*, to appear.

Modeling Extremal Dependence with Copulas

Johanna G. Nešlehová, McGill University

Rare events such as large financial losses, insurance claims, and environmental catastrophes are of prime concern in risk management. In this talk, I will discuss how the dependence between extreme risks can be assessed and modelled using copula-based techniques. To guard against the underestimation of dependence at extreme levels, extreme-value copula models are often used. Thanks to much recent progress, this class of models is quite well understood and various techniques for model simulation, fitting and validation are available. However, extreme-value copulas are asymptotic dependence structures and as such not always adequate for observed data. In such pre-asymptotic settings, the recently proposed Archimax copula class [1] may be a viable alternative. As I will explain, Archimax copulas are not necessarily extremevalue, but designed to be in the domain of attraction of the latter as to avoid risk underestimation. Inference techniques for Archimax copula models are currently being developed [1] and I will report on recent progress.

- Charpentier A., Fougères A.-L., Genest C., Nešlehová J.G., Multivariate Archimax copulas, Journal of Multivariate Analysis, 126, 118–136, 2014.
- [2] Chatelain, S., Fougères A.-L., Nešlehová J.G., Inference for mutlivariate Archimax copulas, Working paper, 2017.

VaR Bounds for Joint Portfolios with Dependence Constraints

Giovanni Puccetti, University of Milan, Italy

We derive lower and upper bounds for the Value-at-Risk of a portfolio of losses when the marginal distributions are known and an additional (in)dependence structure is assumed. We provide several actuarial examples showing that the newly proposed bounds strongly improve those available in the literature that are based on the sole knowledge of the marginal distributions.

- [1] Puccetti, G., Rüschendorf, L. and D. Manko (2016). VaR bounds for joint portfolios with dependence constraints. Depend. Model. 368-381.
- [2] Puccetti, G., Rüschendorf, L., Small, D., and S. Vanduffel (2016). Reduction of Value-at-Risk bounds via independence and variance information. Forthcoming in Scandinavian Actuarial Journal.
- [3] Bignozzi, V., Puccetti, G., and L. Rüschendorf (2015). Reducing model risk via positive and negative dependence assumptions. Insurance Math. Econ. 61(1), 17-26.

Replication Methods for Financial Indexes

Bruno Rémillard, HEC Montréal

In this talk I will present statistical tools that can be used in asset management either to track financial indexes or to create synthetic ones. These tools include copula models, optimal hedging, regression and filtering techniques.

At first, these replication techniques were used to try to replicate hedge funds indexes, but nowadays they can also be used to construct Exchange Traded Funds.

Two Applications of the Martingale Method to Stochastic Control Problems in Finance and Insurance

Hongcan Lin, University of Waterloo David Saunders, University of Waterloo Chengguo Weng, University of Waterloo.

We consider two applications of the martingale method of stochastic control to problems from finance and insurance. The first problem considers an insurer determining the optimal asset portfolio to support participating contracts issued to policyholders. Both the cases where the contract is defaultable, and when it is fully protected are considered. We derive a closed form optimal strategy for companies with an Sshaped utility function, and compare this strategy to CPPI, OBPI strategies, as well as the optimal strategy subject to portfolio constraints. In the second problem, we consider the continuous time portfolio selection problem for an investor seeking to maximize a performance ratio. We show that the problem is unbounded for some performance measures popular in practice (the Omega measure in particular), and then analyze a modified problem that is well-posed. In particular, we derive semianalytical expressions for the optimal strategy in the case where the reward and risk are power functions of the excess and deficit with respect to a fixed benchmark return level.

- [1] Lin, H., Saunders, D., and Weng, C., Optimal Investment Strategies for Participating Contracts, 2017.
- [2] Lin, H., Saunders, D., and Weng, C., Performance Ratio Optimization via the Martingale Approach to Stochastic Control, 2017.

Bayesian Finance

Josef Teichmann, ETH Zürich

We consider an abstract two filtration setting to model (large) financial markets: the trader is using information from the smaller filtration whereas the price process is adapted to the larger filtration. We present an FTAP extending seminal work of Kabanov-Stricker in the discrete time setting for small markets. We show that this modeling approach applies to many important real world situations including model uncertainty, non-semimartingale models, Bayesian calibration, etc (joint work with Christa Cuchiero and Irene Klein).

Invited Professional Experts

Trends and Innovation in Risk Management

Christian Bluhm, Group Chief Risk Officer, UBS

Risk management in the financial industry currently is in a transformation process never seen before. Challenging markets, regulatory burden, cost pressure, macroeconomic risks as well as social unrest and political upheaval demand fundamental changes in the way banks are managing risks, processes and technology. The talk provides an overview of current challenges, most recent trends in banking, innovation to respond to the various pressure points and an outlook on where the journey will most likely take us.

Implied Distributions from FX Risk-Reversals and Predictions for the Effect of the Brexit Vote and the Trump Election

Iain J. Clark, Efficient Frontier Consulting Ltd. Saeed Amen, Cuemacro Ltd.

In May 2016 it was noted that GBPUSD risk reversals were exhibiting very unusual behaviour - namely, extreme skew in short dated tenors but relatively flat smiles thereafter. This is a most unusual volatility signature and the connection with the upcoming Brexit referendum vote was immediately made. The speaker, as a matter of urgency given the topical nature of the pre-Brexit market, performed an analysis with the co-author on implied distributions for the market expectations for GBPUSD around the referendum date (23 June 2016), with predictions for spot thereafter. The paper [1] was uploaded to SSRN on 13 June, in which we identified empirical evidence in the volatility skew for a fall in GBPUSD from 1.4390 to the range 1.10 to 1.30 in the event of a Leave vote – a downward move of 10-25%.

Our predictions were borne out when the referendum result was announced and sterling fell from 1.50 to 1.33 - a downward move of 11.3% - in a matter of hours. Subsequent to this analysis, we applied similar methods to the Mexican peso quoted versus the US dollar (USDMXN) immediately before the 2016 US election and we were able to predict peso devaluation into a range of 20-24 pesos per dollar in the event of a Trump victory, which was borne out by subsequent events. This analysis was inspired by earlier work [2] in the previous calendar year where implied distributions were used to assess the likelihood of pegged currency regime shifts occurring.

In this talk I will go through our analysis of the information embedded in the volatility skew and the basis for our predictive analysis.

- Clark I. J., Amen S., Implied Distributions from GBPUSD Risk-Reversals and Implications for Brexit Scenarios, Working paper, 2016. http://ssrn.com/ abstract=2794888.
- [2] Clark I.J., Modelling Pegged Currencies Examples from 2015: EURCHF, US-DCNY and USDARS, Wilmott, 2016, 51–59.

Changing Risk Landscapes and Innovations - What does this mean for Insurers?

Bernhard Kaufmann, Munich Re

The insurance industry worldwide has faced numerous changes and innovations in recent years. These essentially arise from the following three developments:

1. A changing risk landscape

Following the Brexit referendum result and the election of Donald Trump as president of the USA, uncertainties have clearly increased on the financial markets as well as in the political field. Against the background of forthcoming elections in Europe in 2017 and the general rise of populism, the "Vox populi risk" for example is becoming increasingly manifest. Risk Outlooks and Risk Radars identify additional changing or emerging risks: Climate change, terrorism, uncontrolled migration and water shortages are some of the issues to which society, as well as the insurance industry, must find a response in many ways.

2. Digitalisation, big data and automation

Digitalisation, big data and automation simultaneously present opportunities and challenges for insurers. Digitalisation in particular offers new ways to address customers and develop marketing and insurance solutions, which change the traditional business model of the insurance industry. On the other hand, digitalisation and big data offer multiple new possibilities for analysing and assessing risks, making the uninsurable insurable and supporting processes with the aid of AI. Some insurance providers already use information from social networks or wearables to better assess their customers' risks, for example.

3. New regulatory demands

Around the world, regulatory requirements on the insurance industry will change further in the coming years. Solvency II in Europe, C-ROSS in China and SAM in South Africa are just a few examples of risk-based supervisory systems to be introduced. Moreover, global regulatory requirements and reporting standards, such as ComFrame and IFRS 17, which are currently being developed will have a significant impact on the insurance industry.

This presentation contains practical examples from the three areas outlined above and highlights their significance for the insurance industry. It presents approaches and solutions that insurers are using to prepare for the risks and challenges ahead and looks at how Munich RE in particular is dealing with the changes and innovations.

Predictive Model for Mental Illness in German Disability Business

Dr. Frank Schiller, Munich Re

Disability insurance (DI) in Germany offers income protection to individuals. One of the main causes for claims are mental illnesses and, thus, it is crucial for underwriting and claims management to fully understand the risk drivers. Using modern predictive methods we deepen such considerations in two regards to enhance the design and management of the insurance product:

- First, we focus on the prediction of DI claims specifically due to mental illness. Additionally, we aim to understand the relationship between certain risk factors and mental illness diseases in contrast to their impact on other benefit triggers.
- We consider a wide range of predictor variables as potential risk factors. The basis is internal policy data from a large pool of German Life primary insurers enhanced by publicly available external data such as population density and unemployment rates.

Predictive models can be used to improve many existing functions along the value chain of a life insurer. Two examples of possible applications are presented in detail: in combination with the expertise of Munich Re's medical doctors, the proposed model could reduce the complexity of the underwriting process and trigger additional underwriting questions or the request for a medical report only in case of a high probability of claim due to mental illness. As a second example, claims management could be enhanced by cross-checking the plausibility of incoming claims with cause of claim mental illness.

Invited Talks

Optimal Deterministic Investment Strategies for Insurers

Nicole Bäuerle, Karlsruhe Institute of Technology Ulrich Rieder, Ulm University

We consider an insurance company whose risk reserve is given by a Brownian motion with drift and which is able to invest the money into a Black-Scholes financial market. As optimization criteria, we treat mean-variance problems, problems with other risk measures, exponential utility and the probability of ruin. Following recent research (see [2]), we assume that investment strategies have to be deterministic. This leads to deterministic control problems, which are quite easy to solve. Moreover, it turns out that there are some interesting links between the optimal investment strategies of these problems. Finally, we also show that this approach works in the Lévy process framework. The talk is based on [1].

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Optimal Portfolio Choice with Benchmarks

Carole Bernard, Grenoble EM, Vrije Universiteit Brussel, Rob H. De Staelen, Ghent University, Steven Vanduffel, Vrije Universiteit Brussel

We construct an algorithm that allows to numerically obtain an investor's optimal portfolio under general preferences. In particular, the objective function and risks constraints may be driven by benchmarks (reflecting state-dependent preferences). We apply the algorithm to various classic optimal portfolio problems for which explicit solutions are available and show that our numerical solutions are compatible with them. This observation allows to conclude that the algorithm can be trusted as a viable way to deal with portfolio optimization problems for which explicit solutions are not in reach.

On the Optimality of Path-Dependent Structured Funds

Philippe Bertrand, Aix-Marseille Université

This paper examines the suitability of standard financial structured products whose performances are based on smoothing the return of a given risky underlying asset while providing a guarantee at maturity. Using various assumptions about the customers attitudes towards risk, we show that such standardized products are not optimal, even if the financial market volatility is constant. As a by-product, we provide the optimal portfolio value in the regret/rejoice framework. Using the notion of compensating variation, we determine the monetary losses of providing these standardized products instead of the optimal ones to the customers.

Polynomial Diffusion Models for Life Insurance Liabilities

Francesca Biagini, University of Munich Yinglin Zhang, University of Munich

In this talk we investigate the problem of pricing and hedging portfolios of life insurance liabilities under the new approach of combining the benchmark methodology and the existence of a polynomial diffusion state variable, which drives the reference market. In our model, we focus in particular on the case when the state variable takes value in a compact space following [2]. We consider on the market OIS bonds as well as longevity bonds, both modeled as function of the state variable representing the underlying risk factors, possibly including macro-economic variables, environmental and social indicators. In this way we also introduce a dependence structure between OIS short rate and mortality intensity.

This talk is based on [1].

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Data-Driven Nonlinear Expectations

Samuel N. Cohen, University of Oxford

In stochastic decision problems, one often wants to estimate the underlying probability measure statistically, and then to use this estimate as a basis for decisions. We shall consider how the uncertainty in this estimation can be explicitly and consistently incorporated in the valuation of decisions, using the theory of nonlinear expectations.

Thresholded Regular Vine Copulas with Applications to Portfolio Risk

Claudia Czado, Technische Universität München Thomas Nagler, Technische Universität München Christian Bumann, Technische Universität München

Vine copulas are flexible dependence models and widely used for risk analysis of financial portfolios. They build a dependence structure on *d* assets from a hierarchy of d(d-1)/2 bivariate copulas. When the number of assets *d* is large ($d \gg 50$), the number of parameters quickly exceeds the number of observations available for model selection and parameter estimation which makes the model prone to overfitting. To alleviate this, we introduce the concept of thresholded vine copulas: All bivariate copulas whose strength of dependence is below a certain threshold are set to independence. This induces sparsity in the dependence structure and reduces the number of parameters. We illustrate the benefits of the thresholded model in VaR forecasting for a large portfolio of stocks.

Multiple Curve Interest Rate Modelling Allowing for Negative Rates

Ernst Eberlein, University of Freiburg

A multiple curve forward process as well as a multiple curve forward rate model is developed. In both approaches time-inhomogeneous Lévy processes are used as drivers. Negative interest rates are taken into account in a natural way. We derive valuation formulas for standard interest rate financial products such as caps and floors or digital interest rate options. Some calibration results are presented where we also consider data in the setting of a two price economy, thus exploiting explicitly bid and ask prices. The talk is based on joint work with Christoph Gerhart and Zorana Grbac.

Intrinsic Risk Measures

Walter Farkas, University of Zurich, Swiss Finance Institute and ETH Zürich Alexander Smirnow, University of Zurich and ETH Zürich

Monetary risk measures are usually interpreted as the smallest amount of external capital that must be added to a financial position to make it acceptable. We propose a new concept: intrinsic risk measures and argue that this approach provides a direct path from unacceptable positions towards the acceptance set. Intrinsic risk measures use only internal resources and return the smallest percentage of the currently held financial position becomes acceptable. While avoiding the problem of infinite values, intrinsic risk measures allow a free choice of the eligible asset and they preserve desired properties such as monotonicity and quasi-convexity. A dual representation on convex acceptance sets is derived and the link of intrinsic risk measures to their monetary counterparts on cones is detailed.

Learning and Sparse Control of Multi-Agent Systems

Massimo Fornasier, Technische Universität München

In the past decade there has been a large scope of studies on mathematical models of social dynamics. Self-organization, i.e., the autonomous formation of patterns, has been so far the main driving concept. Usually first or second order models are considered with given predetermined nonlocal interaction potentials, tuned to reproduce, at least qualitatively, certain global patterns (such as flocks of birds, milling school of fish or line formations in pedestrian flows etc.). However, often in practice we do not dispose of a precise knowledge of the governing dynamics. In the first part of this talk we present a variational and optimal transport framework leading to an algorithmic solution to the problem of learning the interaction potentials from the observation of the dynamics of a multiagent system. Moreover, it is common experience that self-organization of a society does not always spontaneously occur. In the second part of the talk we address the question of whether it is possible to externally and parsimoniously influence the dynamics, to promote the formation of certain desired patterns. In particular we address the issue of finding the sparsest control strategy for finite agent models in order to lead the dynamics optimally towards a given outcome. We eventually mention the rigorous limit process connecting finite dimensional sparse optimal control problems with ODE constraints to an infinite dimensional sparse mean-field optimal control problem with a constraint given by a PDE of Vlasov-type, governing the dynamics of the probability distribution of

the agent population. A summary of this talk and related references can be found in [1].

 M. Fornasier. Learning and sparse control of multiagent systems, In Proc. 7thECM, 2016. https://www-m15.ma.tum.de/foswiki/pub/M15/ Allgemeines/PublicationsEN/Massimo_Fornasier_proc_7thECM.pdf

Optimal Asset Allocation in Life Insurance: An Analysis of Flexibility Riders

Peter Hieber, University of Ulm An Chen, University of Ulm Thai Nguyen, University of Ulm

Traditional life insurance contracts that include long-term return guarantees get less and less popular: The decrease in guaranteed rates makes such products unattractive for the policyholder while insurance companies need to provide more solvency capital (following the introduction of Solvency II). To still acquire new business, insurance companies need to be more innovative in their contract design. We examine so called flexibility riders, where the policyholder can decide on the riskiness of the insurance contract's investment strategy (examples of such products are *Allianz Index Select* or *Generali Rente Profil Plus*). Dependent on the policyholder's individual preferences, we determine the optimal investment decision for such products. Mathematically, this requires results on non-concave utility maximization (see, e.g., [1], [1]). If the policyholder's preferences are constant relative risk aversion (CRRA), we determine closed-form expressions for the utility-maximizing investment strategy of the policyholder. In numerical examples, we provide insights on how to improve insurance contract design to better suit the policyholder's needs.

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Role of Information and Portfolio Optimisation

Monique Jeanblanc, Université d'Evry

In this talk, we shall study how an informed agent can take into account some information not included in the prices to make profit. We shall also emphasize that prices depend on the filtration, especially in a default setting.

Structural Analysis of the European Sovereign Bond Network

Martin Keller-Ressel, TU Dresden

Inspired by methods from image and video recognition, notably [1, 1], we propose a mathematical framework to extract structure and information from bipartite networks of investors and assets. The proposed method can be described as a weighted decomposition of the network's adjacency matrix into a low-rank component, a sparse component and a small residual matrix. While the low-rank component represents a low-dimensional market portfolio that is held by the bulk of investors, the sparse component contains individual deviations from this market portfolio and therefore the most salient information on investor behavior. We illustrate the method on data from the European Banking Authority which contains the sovereign bond holdings of 123 banks from the Eurozone and Norway in the year 2014. In particular, we find that most deviations from the market portfolio can be attributed to 'home bias' and other forms of regional and historical bias.

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Forward versus Spot Modeling

Jan-Frederik Mai, XAIA Investment

It is possible to base an equity derivatives pricing model on an exogenously modeled stochastic process representing either the share price (spot), or the equity forward. While the former is the classical approach pioneered by [3], probably the first and most prominent example of the latter technique is [2] (albeit in a commodityand not an equity-setting). While the Black-Scholes spot price approach and the Black's forward approach are equivalent, the introduction of local volatility and/or level-dependent default intensity into the driving process destroys this equivalence - if applied carelessly. This is demonstrated within a defaultable Markov diffusion model for the driving process (either spot or forward). The forward modeling approach seems to be more natural and simpler when there is a need to model discrete (and possibly stochastic) cash dividends, as demonstrated in [1]. Apart from this advantage the decision between forward or spot modeling seems to be a matter of personal taste in most practical applications.

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Systemic Risk Capital Requirements in Financial Networks

Nils Detering, LMU München Thilo Meyer-Brandis, LMU München Konstantinos Panagiotou, LMU München Daniel Ritter, LMU München

The financial crisis has demonstrated that systemic risk due to the interconnectedness of financial-market participants - such as financial institutions, insurers, governments and, even, regulators themselves - can dramatically amplify the consequences of isolated shocks to financial systems and pose a serious threat to prosperity and social stability. The traditional approach to risk control in financial mathematics is to apply risk measures to single institutions. However, this strategy insufficiently captures systemic risk which is propagated through contagion channels, and recent literature has started to develop various approaches to rectify this deficiency.

We here present some results from [1] where we consider a weighted, directed and inhomogeneous random graph as a (random) network model for large financial systems and thoroughly analyze in terms of network statistics to which extent a local shock of defaults can propagate to large parts of the system due to contagion effects. Resorting to earlier results obtained [1] we quantify the final damage after contagion caused by some initial set of defaults and characterize when such financial networks are prone respectively resilient to small initial shocks. Our model allows to study settings that were outside the reach of current methods, in particular the prominent case in which the degree distribution has an unbounded variance. Based on these insights we are then able to determine systemic risk capital requirements for the individual financial institutions such that the financial network becomes resilient. An important feature is that our capital requirements can be determined locally, i.e. each financial institution can compute its capital requirement by merely knowing its own exposures. This is opposed to most other systemic risk allocations in the literature where knowledge of the whole network is required to determine the individual allocations.

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- [2] Detering N., Meyer-Brandis T., Panagiotou K., Ritter D., Managing contagion in financial networks, preprint, 2017.

Implications of Solvency II and the Low Interest Rate Environment on the Asset Management and the Business Model of Insurance Companies

Dr. Peter Ott, Partner KPMG

The asset management of european insurance companies is currently impacted by the low interest rate environment and Solvency II, which is in place since the beginning of 2016. In Solvency I the investment risk was not modelled explicitly. This is quite different now in the new Solvency II regime.

- 1. In the first part I will explain the capital requirement rules of the Solvency IIregulation regarding different types of investments (real estate, equity, bonds, alternative investments) and will discuss the possible impacts. I will discuss potential changes in the asset universe and in the asset allocation of typical insurance companies (life, health, and property-casualty insurance companies).
- 2. In the second part I will discuss the impacts of the low interest rate environment on the solvency ratio and their development over the years. The Solvency ratio is quite different for traditional life insurance companies, health insurance companies and property casualty insurance companies. I will present a KPMG market study with results and impacts of stresstests for a typical life, a typical health and a typical property casualty insurance company.
- 3. In the third part I will give an overview on the impacts of the low interest rate environment and the SII-regime on the asset liability management and the liability driven investment management. I will discuss four areas of improvement

in ALM and Liability driven investment management for insurers and give an overview about potential trends in this area.

4. In the last chapter I will discuss the impact of the low interest rate environment and the Solvency II regime on the life insurance products and give a conclusion about the future of the life insurance business.

Negative Management Fees in Times of Negative Interest Rates

Luis Seco, University of Toronto, Sigma Analysis & Management

Low and Negative interest rates have re-classified traditional bonds as instruments than can no longer match liabilities of insurance companies and pensions. At the same time, they are opening up the path for innovative investment products where positive coupon-like payments can be extracted from bond-like structures. This talk will survey some of these new investment products which use investment managers as a source of income for investors, creating a framework that we describe as "negative management fees".

Solvency II - Or How to Swipe the Downside Risk Under the Carpet

Stefan Weber, Leibniz Universität Hannover

Under Solvency II the computation of capital requirements is based on value at risk. Value at risk (V@R) is a quantile-based risk measure and neglects extreme risks in the tail. A serious deficiency of V@R is that firms can hide their downside risk in corporate groups. They can always reduce their total capital requirement to zero via appropriate transfer agreements within a group structure consisting of sufficiently many entities. We prove that this result holds for a much larger class of non-convex risk measures and explicitly construct the corresponding allocation of the group portfolio.

A Complete Theory for Replicating Portfolios

Jan Natolski, Universität Augsburg Ralf Werner, Universität Augsburg

In the last few years, the first theoretical foundations for replicating portfolios probably the most prevailing technique for risk capital calculation in life insurance - have been given in a series of papers by Beutner, Pelsser and Schweizer. We add to this mainly asymptotic line of research on the approximation of the aggregated terminal value distribution of the liabilities under the risk neutral measure by a complete theory concerning the overall effectiveness of the replicating portfolio approach. We first prove that both replication by terminal value and by cash flow matching are consistent with the aim to obtain an accurate approximation not only to the aggregated terminal value distribution, but, more importantly, to an accurate approximation of the distribution of the fair value of liabilities (FVL) after one period. In contrast to the existing literature, our results are not of asymptotic nature but provide exact bounds on the error of the approximation of the FVL distribution and apply to both the risk neutral and the real world measure. We further provide the missing link between the error in the FVL distribution and the error in the resulting risk capital figure, by providing explicit bounds on the latter in terms of the former. One important mathematical tool in our analysis is the observation that in discrete time, the measure change from the real world to the risk neutral measure can be both bounded below and above by a suitable constant in the first period.

Contributed Talks

Hedging Contingent Guarantees in Unit-Linked Life Insurance

Tobias Bienek, Technische Universität München Matthias Scherer, Technische Universität München

We study novel guarantee concepts in unit-linked life insurance, where the guaranteed amount grows contingent upon the performance of the underlying investment fund. In contrast to standard hedging and valuation problems, the fund serves as both the underlying security and the hedge portfolio, rendering common pricing approaches inadequate. By extending the classical portfolio insurance framework of [1, 2], we transform the problem of hedging contingent guarantees into an associated stochastic fixed-point problem and establish conditions for the existence of hedging strategies. Furthermore, we introduce a numerical valuation scheme based on the method of [1]. The proposed framework can also be employed for the risk management of participating life insurance policies.

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Behavioral Risk Adjustments

Matteo Bissiri, Cassa Depositi e Prestiti (CDP) Riccardo Cogo, Cassa Depositi e Prestiti (CDP)

Assets or liabilities with embedded prepayment/extension options are subject to behavioral risk, due to the unpredictable exercise strategy followed by the option holder who does not act purely on the strength of financial convenience. Such behavior results in a lower option value, as seen from the point of view of the option seller. We propose a general framework to model behavioral risk [1], by combining the features of option-based and intensity models (see e.g. [2]; [3]; [4])and by taking advantage of a full parallel with credit portfolio modelling. Our approach is micro-structural, meaning that the aggregate prepayment rate derives from individual decisions. In principle, a detailed characterization of the behavior of a pool of investors can be performed depending on available data. A particular emphasis is placed on the precise definition of behavioral risk, which leads to a specification of a behavioral risk adjustment (β VA), in line with the recent development of XVA methodology (see e.g. [5]). Analogies with KVA calculations [6] and the recent Basel standards for measuring prepayment risk in the banking book are also discussed [7].

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Joining Diversification and Optimization for Asset Allocation

Francesco Cesarone, Università degli Studi Roma Tre - Dipartimento di Studi Aziendali

Andrea Scozzari, Facoltà di Economia, Università degli Studi Niccolò Cusano -Telematica, Rome, Italy Fabio Tardella, Sapienza Università di Roma - MEMOTEF

The classical approach to portfolio selection calls for finding a feasible portfolio that optimizes one of the several proposed risk measures, or (expected) utility functions, or performance indexes. However, the optimization approach might be misleading due to the difficulty of obtaining good estimates for the parameters involved in the function to be optimized and to the high sensitivity of the optimal solutions to the input data.

This observation has led some researchers to claim that a straightforward capital diversification, i.e., the Equally Weighted portfolio can hardly be beaten by an optimized portfolio [3]. However, if the market contains assets with very different intrinsic risks, then this leads to a portfolio with limited total risk diversification. Therefore, alternative risk diversification approaches to portfolio selection have been proposed, such as the practitioners' approach of taking weights proportional to $1/\sigma_i$, where σ_i is the volatility of asset *i*. A more thorough approach to risk diversification requires to formalize the notion of risk contribution of each asset, and then to manage it by a model. For example the *Risk Parity* approach (see [5], and references therein) aims at a portfolio where the total risk contributions of all assets are equal among them [4]. The original risk parity approach was applied to volatility. However alternative risk measures can also be considered (see, e.g., [1]). It can also be shown that the Risk Parity approach is actually dominated by *Equal Risk Bounding* [2], where the total risk contributions of all assets are bounded by a common threshold which is then minimized. Furthermore, several alternative approaches to diversify risk have recently appeared in the literature.

We propose here a new approach that tries to reduce the impact of data estimation errors and to join the benefits of the optimization and of the diversification approaches by choosing the portfolio that is best diversified (e.g., Equally Weighted or Risk Parity) on a subset of assets of the market, and that optimizes an appropriate risk, or utility, or performance measure among all portfolios of this type. We show that this approach yields portfolios that are only slightly suboptimal in-sample, and generally show improved out-of-sample performance with respect to their purely diversified or purely optimized counterparts.

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Imputation of Complex Dependent Data: A Copula-Based Approach

F. Marta L. Di Lascio, Free University of Bozen-Bolzano, Italy Simone Giannerini, University of Bologna, Italy

Missing data occur in almost all the surveys and data collections. In risk management, for example, an institution might not have enough data to estimate risk components, like the probability of default, and some reconstruction methods should be used. Handling missing data requires resorting to imputation methods since restricting the analysis to complete cases leads to loss of precision and invalid inferences [5]. The choice of the most appropriate imputation method depends on many elements. We present an imputation method that can be used when the focus in on the multivariate dependence structure of the data generating process. The method, called CoImp [1, 2], is based on the copula function [6] and makes it possible to impute multivariate missing data with generic patterns and complex dependence structure. The CoImp is a stochastic single imputation method and employs conditional density functions of the missing variables given the observed ones to fill in each missing (multivariate) value. These functions can be derived analytically once parametric models for the margins and the copula are specified. When analytical derivations are not feasible, the margins are estimated non-parametrically through local likelihood methods [4]. We describe both the analytic and the semiparametric version of the copula-based imputation method and investigate their performance in terms of preservation of both the dependence structure and the microdata through Monte Carlo studies. Moreover, the method has been implemented and made available through the R package CoImp [3]. We provide an illustration of how to handle the imputation through the R package, i.e. a description of its main functions, their output and usage on real data sets.

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Hedge Fund Seeding via Fees-for-Seed Swaps under Idiosyncratic Risk

Christian Ewald, Adam Smith Business School, University of Glasgow Hai Zhang, Adam Smith Business School, University of Glasgow

We develop a dynamic valuation model of the hedge fund seeding business by solving the consumption and portfolio-choice problem for a risk-averse manager who launches a hedge fund through a seeding vehicle. This vehicle, i.e. fees-for-seed swap, specifies that a strategic partner (seeder) provides a critical amount of capital in exchange for participation in the funds revenue. Our results indicate that the new swap not only solves the serious problem of widespread financing constraints for new and early-stage funds (ESFs) managers, but can be highly beneficial to both the manager and the seeder if structured properly.

Regime Switching Vine Copula Models for Global Equity and Volatility Indices

Holger Fink, Nürtingen-Geislingen University & LMU München Yulia Klimova, Technische Universität München Claudia Czado, Technische Universität München Jakob Stöber, Technische Universität München

For nearly every major stock market there exist equity and implied volatility indices. These play important roles within finance: be it as a benchmark, a measure of general uncertainty or a way of investing or hedging. It is well known in the academic literature that correlations and higher moments between different indices tend to vary in time. However, to the best of our knowledge, no one has yet considered a global setup including both, equity and implied volatility indices of various continents, and allowing for a changing dependence structure. We aim to close this gap by applying Markov-switching R-vine models to investigate the existence of different, global dependence regimes. In particular, we identify times of normal and abnormal states within a data set consisting of North-American, European and Asian indices. Our results confirm the existence of joint points in time at which global regime switching between two different R-vine structures takes place.

Implied Risk Aversion: An Alternative Rating System for Retail Structured Products

Sebastian Geissel, HSBC Germany

This talk proposes implied risk aversion as a rating methodology for retail structured products. Implied risk aversion is based on optimal expected utility risk measures (OEU) as introduced by [1] and, in contrast to standard VaR-based ratings, takes into account both the upside potential and the downside risks of such products. In addition, implied risk aversion is easily interpreted in terms of an individual investor's risk aversion: A product is attractive (unattractive) for an investor if its implied risk aversion is higher (lower) than his individual risk aversion. We illustrate our approach in a case study with more than 15000 short-term warrants on DAX that highlights some differences between our rating system and VaR: Implied risk aversion is sensitive to the pricing of products and thus able to identify potentially favorable products. In particular, implied risk aversion is in general not monotone with respect to strike levels of vanilla options.

 Fink H., Geissel S., Sass J., Seifried F.T., Implied Risk Aversion: An Alternative Rating System for Retail Structured Products, Preprint, Available online at SSRN, 2015.

Choquet Integrals and Risk Measures

Miryana Grigorova, Centre for Risk and Insurance, Hannover

The issue of uncertainty (or ambiguity) has attracted considerable interest in the recent decades in mathematical finance and actuarial sciences. There is an increasing awareness that choosing a particular probabilistic model might be too restrictive to allow for the taking into account of the complexity of real-life decision making. In this talk, we place ourselves in the framework of ambiguity modelled by an initial capacity (i.e. a monotone normalized set function, generalizing the notion of probability measure). We present extensions of the notions of increasing, and increasing convex stochastic dominance relations, well-known in the case of a probability measure, to our more general setting. We characterize these "generalized" relations in terms of distribution functions and quantile functions with respect to the initial capacity. We then consider the classes of risk measures (defined on the space of bounded measurable functions) having the properties of comonotonic additivity and consistency with respect to a given "generalized" stochastic dominance relation. These classes of risk measures are characterized in terms of Choquet integrals with respect to a "distortion" of the initial capacity. A Kusuoka-type characterization of the class of monetary risk measures having the properties of comonotonic additivity and consistency with respect to the "generalized" increasing convex stochastic dominance is also established. If time permits, we will also present generalizations of Song-Yan's results on consistent comonotonic subadditive and comonotonic convex risk measures to our framework.

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Geostatistical Modeling for Financial Data

Amelie Hüttner, Technische Universität München Matthias Scherer, Technische Universität München Benedikt Gräler, Ruhr-Universität Bochum

When jointly modeling a large number of financial assets for portfolio or risk management purposes, a crucial question is the proper modeling of the dependence between the considered assets. We study a novel approach borrowed from geostatistics which allows for a simple representation of dependence by means of a correlation function, and also for easily taking into account new data points. The necessary adjustments when intending to apply geostatistical methods to the high-dimensional framework that entails the modeling of financial data are discussed, and the application of the method is illustrated in an example involving credit spread data for the constituents of the iTraxx Europe Index, the index containing the most liquidly traded CDS Names in Europe.

Non-linear Dependence Structure of Cyber Risk

Martin Eling, University of St. Gallen Kwangmin Jung, University of St. Gallen

Many experts claim that cyber risks are correlated, but so far only little empirical evidence exists. We consider 3,327 data breach events in the time period 2005 to 2016 and identify a non-linear dependence between different types of attacks and different types of industries by applying the pair copula methodology. Different from the literature in data breach modeling, this study conducts the distribution fitting for frequency and severity on monthly and quarterly bases. In order to detect the best fit method for the dataset, we implement two pair copula estimations both with parametric copula functions and with nonparametric copula with Bernstein polynomials as a comparison study. We find that nonparametric pair copula structure with Bernstein polynomials is the better model based on AIC to describe the potential lower tail dependence between different attacks and industries. Our findings are important for risk managers and actuaries working on the implementation of cyber insurance policies. We illustrate the usefulness of our results in two applications on risk measurement and pricing by employing the collective risk model with monthly and quarterly risk arrivals.

Determination of Optimal Retention Level Based on Different Measures

Başak Bulut Karageyik, Department of Actuarial Sciences, Hacettepe University Şule Şahin, Department of Actuarial Sciences, Hacettepe University

This paper deals with the optimal retention level under four competitive criteria: survival probability, expected profit, variance and expected shortfall of the insurer's risk. The aggregate claim amounts are assumed to be distributed as compound Poisson and the individual claim amounts are distributed exponentially. We present an approach to determine the optimal retention level which maximises the expected profit and the survival probability and minimises the variance and the expected shortfall of the insurer's risk. In decision making process, we concentrate on multi attribute decision making methods: The Technique for Order of Preference by Similarity to ideal Solution (TOPSIS) and The VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) methods with their extension versions. We also provide comprehensive analysis for determination of optimal retention level under both the expected value and standard deviation premium principles.

Stress Testing and CoVaR-Prediction using D-Vine Quantile Regression

Daniel Kraus, Technische Universität München Claudia Czado, Technische Universität München

Quantile regression, that is the prediction of conditional quantiles, has steadily gained importance in statistical modeling and financial applications. We introduce a new semiparametric quantile regression method based on sequentially fitting a likelihood optimal D-vine copula to given data resulting in highly flexible models with easily extractable conditional quantiles. This new methodology allows us to conduct stress tests with any number of stressed covariates, facilitating the measurement of systemic risk of individual companies or entire industry branches. Analyzing the log returns of the CDS spreads of international banks and insurances we find out that the spillover effects of financial distress are mainly driven by geography rather than financial sectors. Finally, we show how D-vine quantile regression can be used to predict the conditional Value-at-Risk of a company in stressed as well as non-stressed scenarios.

Calculating Capital Charges for Sector Concentration Risk

Cornelius Kurtz, European Central bank Eva Lütkebohmert, University of Freiburg Julian Sester, University of Freiburg

We propose a methodology to quantify capital charges for concentration risk when economic capital calculations are conducted within a multi-factor Merton framework. The concentration charge is defined through the impact of the sector on the portfolio loss curve. We propose two ways of measuring this effect: The first method relies on Monte Carlo simulation but has the advantage of not requiring the calibration of additional parameters, and hence is easily applicable for banks which perform simulations. The second approach is a tractable, analytical formula which provides an efficient approximation to the first method. The proposed approach implies a simple and intuitive allocation of the resultant capital charge and is highly suitable for calculation of capital charges for sector concentration risk under Pillar 2 of the Basel regulatory framework.

Chebyshev Interpolation for Parametric Option Pricing

Maximilian Gaß, Technische Universität München Kathrin Glau, Technische Universität München Mirco Mahlstedt, Technische Universität München Maximilian Mair, Technische Universität München

Recurrent tasks such as pricing, calibration and risk assessment need to be executed accurately and in real-time. We concentrate on Parametric Option Pricing (POP) and show that polynomial interpolation in the parameter space promises to reduce runtimes while maintaining accuracy. The attractive properties of Chebyshev interpolation enable us to identify criteria for (sub)exponential convergence and explicit error bounds. We show that these results apply to a variety of European (basket) options and affine asset models. Numerical experiments confirm our findings. Exploring the potential of the method further, we empirically investigate the efficiency of the Chebyshev method combined with Monte-Carlo for multivariate and path-dependent options. For a wide and important range of problems, the Chebyshev method turns out to be more efficient than parametric multilevel Monte-Carlo.

 Gaß M, Glau K, Mahlstedt M, Mair M, Chebyshev Interpolation for Parametric Option Pricing. Preprint (First version 2015), ArXiv:1505.04648v2,

Generalized Additive Models for Pair-Copula Constructions: An Application to Intraday FX Returns

Thomas Nagler, Technische Universität München Thibault Vatter, École Polytechnique Fédérale de Lausanne

Pair-copula constructions are flexible models for the dependence in a random vector and have attracted a lot of interest in recent years. We use generalized additive models to extend pair-copula constructions to allow for effects of covariates on the dependence parameters. We let each pair-copula parameter depend directly on the covariates in a parametric, semi-parametric or non-parametric way. We use our method to investigate the time-varying dependence structure between the intraday returns on four major foreign exchange rates.

[1] Vatter T, Nagler T, Generalized additive models for pair-copula constructions, arXiv:1608.01593 [stat.ME], 2016.

Herding and Stochastic Volatility

Walter Farkas, University of Zurich and ETH Zurich Ciprian Necula, University of Zurich and Bucharest University of Economic Studies Boris Waelchli, University of Zurich

In this paper we develop a one-factor non-affine stochastic volatility option pricing model where the dynamics of the underlying is endogenously determined from micro-foundations. The interaction and herding of the agents trading the underlying asset induce an amplification of the volatility of the asset over the volatility of the fundamentals. Although the model is non-affine, a closed form option pricing formula can still be derived by using a Gauss-Hermite series expansion methodology. The model is calibrated using S&P 500 index options for the period 1996-2013. When its results are compared to some benchmark models we find that the new non-affine one-factor model outperforms the affine one-factor Heston model and it is competitive, especially out-of-sample, with the affine two-factor double Heston model.

Prioritization of Dependent Actuarial Risks: Stochastic Majorization

Ezgi Nevruz, Hacettepe University Kasırga Yıldırak, Hacettepe University

Risk prioritization aims to provide fair and accurate standards in order to compare risks by considering their characteristics. In this study, we aim to investigate the aggregate claims of different risk classes in terms of their comparability and orderability under the dependency assumption. For this aim, we use a stochastic ordering relation called "stochastic majorization" which is proposed in the frame of partial order theory. "Order-preserving" functions are very beneficial in this context, since we use risk measures defined as functions to evaluate risks. A real-valued function which preserves the ordering of majorization is said to be "Schur-convex" function [1]. For the risk assessment, it is significant to use a measure reflecting the risk of a portfolio sufficiently and accurately. Therefore, we choose a risk measure that fulfils the properties of Schur-convexity and we use it to order the aggregate claims with the stochastic majorization.

Keywords Aggregate claims, Dependent actuarial risks, Partial order theory, Risk measure, Stochastic majorization, Schur-convexity.

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Managing Risks in Collateralized FX Markets

Andrea Pallavicini, Imperial College, London Nicola Moreni, Banca IMI, Milan

The shortage of funding sources following the financial crisis of 2007 forced central banks to adopt a number of non-standard measures to support financing conditions and credit flows both in domestic and foreign currencies. Despite these efforts, market frictions and dislocations, which were already present before the crisis, strengthened with direct consequence in derivative option prices when an investor requires funding in a foreign currency. Market dislocations may produce additional costs in funding and hedging activities and, during turbulent periods, can also lead to severe liquidity shortages.

This paper sets within this context and aims to shed some light both from a theoretical and a market practice point of view. We extend the previous work of [1] to discuss how to manage risks in presence of market dislocations and of market incompleteness. In particular, we present a general derivation of the arbitrage-free pricing framework for multiple-currency collateralized products reflecting the policy adopted to fund in a foreign currency. Then, starting from real market data, we apply these results to calculate prices and sensitivities of cross-currency swaps under different market situations. Moreover, we present the main practical problems arising from the way the market is quoting liquid instruments and we discuss the theoretical requirements to implement curve bootstrapping and the approximations usually taken to practically implement the procedure.

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Examples of WWR in CVA induced by Devaluations on Default

Damiano Brigo, Imperial College Nicola Pede, Imperial College

When calculating *Credit Valuation Adjustment* (CVA), the interaction between the portfolio's exposure and the counterparty's credit worthiness is referred to as *Wrong–Way Risk* (WWR). Making the assumption that the Brownian motions driving both the market (exposure) and the (counterparty) credit risk–factors dynamics are correlated represents the simplest way of modelling the dependence structure between these two components. For many practical applications, however, such approach may fail to account for the right amount of WWR, thus resulting in misestimates of the portfolio's CVA. We present a modelling framework where a further — and indeed stronger — source of market/credit dependence is introduced through devaluation jumps on the market risk–factors' dynamics. Such jumps happen upon the counterparty's default and are a particularly realistic feature to include in case of sovereign or systemically important counterparties. Moreover, we show that, in the special case where the focus is on FX/credit WWR, devaluation jumps provide an effective way of incorporating market information coming from quanto CDS basis spreads and we derive the corresponding CVA pricing equations as a system of coupled PDEs.

Static vs Adapted Optimal Execution Strategies in Two Benchmark Trading Models

Clément Piat, Imperial College London Damiano Brigo, Imperial College London

We consider the optimal solutions to the trade execution problem in the two different classes of i) fully adapted or adaptive and ii) deterministic or static strategies, comparing them. We do this in two different benchmark models. The first model is a discrete time framework with an information flow process, dealing with both permanent and temporary impact, minimizing the expected cost of the trade. The second model is a continuous time framework where the objective function is the sum of the expected cost and a value at risk (or expected shortfall) type risk criterion. Optimal adapted solutions are known in both frameworks from the original works of Bertsimas and Lo (1998) and Gatheral and Schied (2011). In this paper we derive the optimal static strategies for both benchmark models and we study quantitatively the improvement in optimality when moving from static strategies to fully adapted ones. We conclude that, in the benchmark models we study, the difference is not relevant, except for extreme unrealistic cases for the model or impact parameters. This indirectly confirms that in the similar framework of Almgren and Chriss (2000) one is fine deriving a static optimal solution, as done by those authors, as opposed to a fully adapted one, since the static solution happens to be tractable and known in closed form.

 Brigo D, Piat C, Static vs Adapted Optimal Execution Strategies in Two Benchmark Trading Models, 2016.

Bounds on Integrals with Respect to Copulas

Michael Preischl, Technische Universität Graz

Assume that we are given a *d*-dimensional random vector (X_1, \ldots, X_d) and a function $f : \mathbb{R}^d \to \mathbb{R}$ that describes the quantity associated with (X_1, \ldots, X_d) which we wish to optimize. We further assume *dependence uncertainty*, i.e. the marginal distributions of X_1, \ldots, X_d are known whereas the dependence structure between the RVs is completely unknown. This setting has been studied on numerous occasions but still many fundamental questions about extremal dependence structures remain open. One particularly interesting task is finding a multidimensional analogon to the two-dimensional concept of complete negative dependence. However, as research (e.g. [2], [3]) suggests, this problem might be too complicated to allow for an easy, general, analytic solution. We present a numerical method to obtain upper and lower bounds on E[f(X)] by discretizing the domain and solving the corresponding assign-

ment problem. This was stated an open problem in [1], where a similar method was proposed for two dimenions.

We further show connections to state-of-the art algorithms, in particular the *rear-rangement algorithm* (RA) by Embrechts, Puccetti and Rüschendorf. As applications, three dimensional dependence measures as well as an example from finance are considered.

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A Model for Share Earnings, Dividends and Prices

A. D. Wilkie, InQA Limited, UK Şule Şahin, Department of Actuarial Sciences, Hacettepe University, Turkey

In this paper we develop an extension to the Wilkie model, introducing share earnings and cover (earnings/dividends) as new variables, and deriving share dividends from them. Earnings are available from April 1962, but only for Non-Financial companies, and for All Shares only from 1992. We construct a composite earnings index from these series. We then find a suitable annual time series model for changes in earnings, and then for cover, which is mean-reverting. We compare this new model with the original model, in which changes in dividends were modelled directly. We also investigate monthly data to give parameters for stochastic interpolation. We observe an unusual change in earnings over 2015-16, considered the implications of this, and show specimen simulations.

Risk Management in Disturbed Times

Peter Schenk, MEAG

In the last couple of years new risks have arisen and the connectivity of risks has increased. This has an impact on asset management. Risk management must be prepared to recognize new financial risk drivers, risk concentrations as well as changed capital market regimes. Thus, model validations and the assessment of model risks as such must play a major role in the context of measurement of risks: Model limitations need to be made clear to any model user and decision maker. And where risk measurement is not even possible due to unknown probabilities and interdependencies a powerful stress testing framework is in place to give senior management an impression of what might happen when certain risks materialize.

Seasonal Stochastic Volatility and Correlation in Agricultural Futures Markets

Lorenz Schneider, Visiting Professor, KPMG Center of Excellence in Risk Management, Technical University of Munich Bertrand Tavin, EMLYON Business School

We introduce a stochastic volatility model based on the CIR/Heston process that incorporates seasonality and the Samuelson effect. We give conditions on the seasonal term under which the corresponding volatility factor is well-defined, and calculate the characteristic function in analytic form. In an empirical part, we calibrate the model to options on Corn, Soybean, Wheat and Sugar futures and find that it can fit these markets closely. We illustrate how the correlation of a pair of futures contracts also becomes seasonal, and the effect this has on prices of calendar spread options. Finally, we set up the model under the physical measure and show how its parameters can be estimated for a time series of futures prices using the Kalman filter.

On a Numerical Method for PDMP Type Risk Models

Michael Preischl, Graz University of Technology, Austria Stefan Thonhauser, Graz University of Technology, Austria Robert F. Tichy, Graz University of Technology, Austria

In [1] we present some new results on the application of quasi-Monte Carlo methods in risk theory. The basic idea of QMC-integration is to use a point set $\{\mathbf{x}_1, \dots, \mathbf{x}_N\}$ from $[0, 1]^s$ and approximate the integral of a suitable function f by a simple average. Then, the Koksma-Hlawka inequality, see [2], states that the error can be bounded in the following way

$$\left|\frac{1}{N}\sum_{n=1}^{N}f(\mathbf{x}_{n})-\int_{[0,1]^{s}}f(\mathbf{x})d\mathbf{x}\right|\leq\mathscr{V}(f)D_{N},$$

where $\mathscr{V}(f)$ is the variation of f and D_N is the discrepancy of the used point set. In the classical setup the assumption of finite $\mathscr{V}(f)$ is very restrictive and an application of the QMC method lacks a theoretical basis in many situations.

In risk theory many quantities of interest, such as ruin probabilities, penalty functions or expected dividend payments, can be characterized as solutions to particular integral equations and their numerical evaluation boils down to the computation of high dimensional integrals. Consequently, QMC-integration is a potential tool for such problems. In this talk we consider a risk model of piecewise-deterministic Markov type and show that new notions of *variation* and *discrepancy*, see [3], can be exploited in this framework. This type of risk model allows for various extensions of the classical risk model and can be used to overcome its static parameter choice, i.e., non-constant drift and jump distribution parameters can be introduced. The results will be illustrated by an evaluation of the discounted penalty function which generalizes the traditional ruin probability.

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CVA Wrong Way Risk via Change of Measure: Actuarial vs Risk Neutral Pricing

Damiano Brigo, Imperial College, London, UK Frédéric Vrins, UCLouvain, Louvain-la-Neuve, Belgium

A key driver of Credit Value Adjustment (CVA) is the possible dependency between exposure and counterparty credit risk, known as Wrong-Way Risk (WWR) [1]. At this time, addressing WWR in a both sound and tractable way remains challenging: arbitrage-free setups have been proposed by academic research through dynamic models but are computationally intensive and hard to use in practice. Tractable alternatives based on resampling techniques have been proposed by the industry, but they lack mathematical foundations. This probably explains why WWR is not explicitly handled in the Basel III regulatory framework in spite of its acknowledged importance. The purpose of this paper is to propose a new method consisting of an appealing compromise: we start from a stochastic intensity approach and end up with a pricing problem where WWR does not enter the picture explicitly. This result is achieved thanks to a set of changes of measure: the WWR effect is now embedded in the drift of the exposure, and this adjustment can be approximated by a deterministic function without affecting the level of accuracy typically required for CVA figures. The performances of our approach are illustrated through an extensive comparison of Expected Positive Exposure (EPE) profiles and CVA figures produced either by (i) the standard method relying on a full Monte Carlo framework and (ii) our driftadjustment approximation. We further analyze the differences between counterparty risk reserves computed under the physical measure via actuarial pricing methods and the CVA price computed using arbitrage-free risk neutral models.

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Liability Driven Investments with a Link to Behavioral Finance

Ludwig Brummer, Technische Universität München Markus Wahl, Technische Universität München Rudi Zagst, Technische Universität München

Liability driven investment (LDI) strategies that take stochastic liabilities into account have become increasingly important for insurance companies and pension funds due to market developments such as low interest rates, high volatility and changes in regulatory requirements. Stochastic liabilities were included in portfolio optimization problems in discrete and continuous time models in several ways. We include aspects from behavioral finance, in particular cumulative prospect theory (CPT). In a CPT framework, we study LDI strategies with extended preference structures and probability distortion. We derive analytical solutions for a CPT portfolio optimization problem in an LDI context. Within an empirical case study, we compare the optimal investment strategies to existing LDI approaches within traditional frameworks.

Location



TUM quantum Lounge Parkring 35 85748 Garching-Hochbrück

From Munich airport to TUM quantum Lounge:

Take any S-Bahn from the airport in direction to "Ostbahnhof". At the city center station "Marienplatz" change to the subway line U6 towards "Garching-Forschungszentrum" and exit at "Garching-Hochbrück". Follow the footpath through the pedestrian underpass (Schleißheimer Straße / B471) to Parkring 35.

Alternatively, take the S-Bahn line S1 to "Neufahrn" and then change to the bus line 219 towards "Garching-Hochbrück".

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Take subway lines U1, U2 or U7 to "Sendlinger Tor", change to the subway line U6 towards "Garching-Forschungszentrum" and exit at "Garching-Hochbrück". Follow the footpath through the pedestrian underpass (Schleißheimer Straße / B471) to Parkring 35.

Food

There will be a lunch break from 12.50pm - 14.00pm every day. **On Wednesday, KPMG is sponsoring lunch at the TUM quantum Lounge for participants of the conference.** On Thursday and Friday, there is no organized lunch, but located on the Business Campus there are several locations we recommend to you:

Freiraum canteen at the center of the Business Campus

- four variable lunch menus
- www.freiraum.rest

Bistro "Im Ernst" next to the EDEKA supermarket

- salads, sandwiches and variable hot lunch menu (5-8 euros)
- daily menu available at http://www.edeka-ernst.de/Speiseplan/speiseplan.html

Bakery "Riedmair" at Parkring 2

• panini, soups, pizza

Italian bistro "Bistro & Wein" at Parkring 4

• variable hot lunch menu

Jagerhof at Schleißheimerstraße 83

• typical Bavarian food

"Campus Imbiss Döner" in front of Bistro "Im Ernst"

• offers kebap, borek and other Turkish food

KEYNOTE SPEAKERS HANSJÖRG ALBRECHER DANIEL BAUER **CHRISTIAN BLUHM DAMIANO BRIGO** IAIN CLARK DAMIR FILIPOVIĆ **BERNHARD KAUFMANN RALF KORN STEVEN KOU STÉPHANE LOISEL ALFRED MÜLLER** JOHANNA G. NEŠLEHOVÁ **BRUNO REMILLARD DAVID SAUNDERS** FRANK SCHILLER **GERHARD STAHL JOSEF TEICHMANN**

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