TotalRisk
Statistics for modelling the risk of financial institutions

Innovation area: Finance

Key Innovator: Kjersti Aas

Partners: DNB, NR, UiO, NTNU

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Scope:

Development of the pair copula construction as a prefered method for the analysis of multiple variables with strong tail dependence in financial applications

Results in 2012 and plans:

Risk management confronts us with heavy-tailed distributions, rapid changes and complex dependencies. This forces us to look beyond standard statistical models to develop more sophisticated methodology. We need to consider both supervised approaches, when much is known in detail about the variables at play, and un-supervised contexts, where adaptive modelling strategies are required to automatically capture variation from data. Our objective is to renew the tools used for total risk modelling in financial institutions, producing more reliable and useful estimates of the risk. Complex dependency and interactions are key aspects. Though extreme events for financial data manifest themselves through high gains and/or losses, very often it is the *co-movement* of underlying instruments in times of crises that triggers such events; the so–called perfect storm scenario. Hence, the modeling of the joint occurrence of extremes ought to be of prime concern, when modeling risk types as credit risk, market and operational risk. Dependence structures are often non-linear, requiring new statistical methods, such as copula-based approaches. We develop new ways to construct multivariate distributions from smaller components, building a theory beyond conditional independence. The distributions of financial returns, credit losses, and operational losses all have multivariate heavy tails. Some of them are skewed, with one tail heavier than the other. We develop models for heavy-tailed and skewed phenomena. Our research results will be validated within our partners, tested and confronted, with the aim to become part of best practice in the years to come.

In 2012 we have worked in five main areas:

(i) Pair-copula constructions: The focus of this activity is to improve the state-of-the art methods for modelling the dependency in the tails of a multivariate distribution.

(ii) Copula model estimation and evaluation: In this sub-project we study different aspects connected to estimation and model evaluation of copulas.

(iii) Rehabilitation of illegal correlation matrices: The aim of this activity is transform a non-positive definite correlation matrix into a legal one using Bayesian methods.

(iv) Improving simulation accuracy: In many financial risk management applications, Monte Carlo simulations have become the standard approach for computing the desired risk measures. However, since one usually is interested in quantiles far out in the tail of the distribution, naïve Monte Carlo simulation would require a very large number of simulations. For DNB's current portfolio not even 5 million simulations is sufficient to obtain the desired accuracy of 99.97% VaR.

(v) For rare event estimation problems, importance sampling (IS) often provides an efficient means of generating low variance estimates. In 2009, (sfi)^2 developed a new IS technique for VaR estimation and Expected Shortfall-based capital allocation that was shown to work well for all sorts of real-world credit portfolios (Reitan & Aas, 2010). In 2012 we have adapted this methodology to DNB's current credit risk model. The result has been implemented in DNBs risk management systems.

In 2013 subprojects (i) and (ii) will continue. These are described in more details below. If the external evaluation of DNBs total risk model taking place in October and November 2012 identifies scientific weaknesses of this model, we might also start one or two new subprojects. However, these will in case not be defined before early 2013.

Pair-copula constructions: In 2013 and 2014 the aim of this activity is twofold:

(i) We want to study the relationship between Bayesian Belief Networks and pair-copula constructions.
(ii) We want to develop new methods for truncating pair-copula constructions.

We hope to produce one paper on each of these themes. In what follows we describe the problems in a bit more detail:

Pair-copula constructions bear many similarities with Bayesian Belief Networks (BBNs). The latter are very much used in practical applications. However, they have almost only been restricted to the multivariate normal or discrete distributions. When faced with continuous data that cannot be captured well with the multivariate Gaussian, the vast majority of work first discretize the data, and then take advantage of the methods that has been made for the discrete case. Copulas offer a flexible mechanism for modelling continuous distributions. Hence, the two frameworks thus complement each other in a way that offers opportunities for fruitful synergic innovations.

For pair-copula constructions (PCCs) to be really useful in practice, one needs to be able to fit such structures to data with more than 20 dimensions. However, a problem with the PCC is that the computational effort required to estimate all parameters grow exponentially with the dimension. Hence, we have previously studied methods for truncating a PCC, where we by a K-truncated PCC means a pair-copula construction for which all pair-copulas with a conditioning set equal to or larger than K are replaced by independence copulas (Brechmann et.

al., 2012). The previously developed truncation methods are not optimal. Hence, for in 2013 we will continue this activity and develop alternative criteria for how to truncate a PCC.

Model evaluation: We have previously shown (Grønneberg and Hjort, 2012) that the arguments leading to the classical AIC does not hold for the case of parametric copula models using the maximum pseudo likelihood procedure. Moreover, we have derived a proper correction, denoted the CIC, the Copula Information Criterion which is fundamentally different from the AIC erroneously used by practitioners. In 2013, we will investigate whether another model validation tool, the focused information criterion (FIC), may be successfully applied to pair-copula constructions. The FIC (Claeskens and Hjort, 2003) is a method for selecting the most appropriate model among a set of competitors for a given data set. Unlike most other model selection strategies, like the AIC, the FIC does not attempt to assess the overall fit of candidate models, but focuses attention directly on the parameter of primary interest with the statistical analysis. This parameter might e.g. be the Value-at-Risk.

Innovation and technology transfer: In addition to the activities described above, our aim for 2013 is trying to identify the added value of some of the tools previously developed in the TotalRisk project to innovation in Norwegian and international financial institutions. More specifically, we will concentrate on two tools:

(i) The Bayesian tool for rehabilitating an illegal correlation matrix.
(ii) The pair-copula constructions

As far as the first innovation is concerned, and earlier version of this tool is already operational at DNB. Regarding the pair-copula constructions, we know from the literature that these structures have been used for e.g. risk management and portfolio optimization. However, we want to more systematically investigate how the PCCs are used in Norwegian and international financial institutions.

Pair-copula workshop: In December 2009 we hosted an international workshop on pair-copula constructions. This workshop was very successful. Since then, the "PCC community" has significantly increased (the current number of citations of the paper Aas et. al, 2009 at Google Scholar is currently 233). Hence, we believe that a new workshop on pair-copula constructions will gather many participants. The plan is to organize such a workshop either late 2013 or spring 2014.

Papers:

Aas, Kjersti; Berg, Daniel: Modelling dependence between financial returns using pair-copula constructions. In DEPENDENCE MODELING: Handbook on Vine Copulae, D. Kurowicka and Harry Joe (eds.), World Scientific Publishing Co., February 2011.

Aas, Kjersti; Czado, Claudia; Frigessi, Arnoldo; Bakken, Henrik: Pair-copula constructions of multiple dependence. Insurance: Mathematics and Economics, 2009; Vol. 44 (2): 182-198.

Berg, Daniel; Aas, Kjersti: Models for construction of multivariate dependence. European Journal of Finance, 2009; Vol. 15(7/8): 639-665.

Berg, Daniel: Copula goodness-of-fit testing: An overview and power comparison. European Journal of Finance, 2009; Vol. 15(7/8): 675-701.

Brechmann, Eike C.; Czado, Claudia; Aas, Kjersti: Truncated regular vines in high dimensions with application to financial data. Canadian Journal of Statistics, 2012; Vol. 40(1): 68-85.

Cooke, Roger; Joe, Harry; Aas, Kjersti: Vines Arise. In DEPENDENCE MODELING: Handbook on Vine Copulae, D. Kurowicka and Harry Joe (eds.), World Scientific Publishing Co., Scheduled Fall 2010.

Dakovic, Rada; Czado, Claudia; Berg, Daniel: Bankruptcy prediction in Norway: a comparison study. Applied Economic Letters, 2010; Vol. 17(17): 1739-1746.

Frigessi, Arnoldo; Løland, Anders; Pievatolo, Antonio; Ruggeri, Fabrizio: Statistical rehabilitation of improper correlation matrices. Quantitative Finance, 2011; Vol. 11(7): 1081-1090.

Grønneberg, Steffen; Hjort, Nils Lid: The Copula Information Criterion, under revision, 2012.

Grønneberg, Steffen: The Copula Information Criterion and its implications for the Maximum Pseudo Likelihood Estimator. In DEPENDENCE MODELING: Handbook on Vine Copulae, D. Kurowicka and Harry Joe (eds.), World Scientific Publishing Co., February, 2011.

Hobæk Haff, I. Comparison of estimators for pair-copula constructions. Journal of Multivariate Analysis, 2012, Vol. 110: 91-105.

Hobæk Haff, Ingrid: Parameter estimation for pair-copula constructions, to be published in Bernoulli Journal, 2012.

Hobæk Haff, Ingrid; Aas, Kjersti; Frigessi, Arnoldo: On the simplified pair-copula construction - simply useful or too simplistic? Journal of Multivariate Analysis, 2010; Vol. 101(5): 1296-1310.

Hobæk Haff, Ingrid; Segers, Johan: Non-parametric estimation of pair-copula constructions with the empirical pair-copula. Submitted, 2012.

Holden, H; Holden, L. Optimal rebalancing of portfolios with transaction costs. Stochastics: An International Journal of Probability and Stochastic Processes, 2012: doi: 10.1080/17442508.2011.651219. 2012.

Holden, Helge; Holden, Lars; Holden, Steinar: Contract adjustment under uncertainty. Journal of Economic Dynamics & Control, 2010; Vol. 34: 657-680.

Løland, Anders; Huseby, Ragnar Bang; Hjort, Nils Lid; Frigessi, Arnoldo: Statistical corrections of invalid correlation matrices. Submitted, 2012.

Martino, Sara; Aas, Kjersti; Lindqvist, Ola; Neef, Linda R; Rue, Håvard: Estimating Stochastic Volatility Models Using Integrated Nested Laplace Approximations. The European Journal of Finance, 2011; Vol. 17(7): 487-503.

Möller, A; Lenkoski, A; Thorarinsdottir, TL. Multivariate probabilistic forecasting using Bayesian model averaging and copulas. In press at Quarterly Journal of the Royal Meteorological Society, 2012.

Quessy, Jean-Francois; Berg, Daniel: Local power analyses of goodness-of-fit tests for copulas. Scandinavian Journal of Statistics, 2009; Vol. 36: 389-412.

Reitan, Trond; Aas, Kjersti: A New Robust Importance Sampling Method for measuring VaR and ES allocations for Credit Portfolios. Journal of Credit Risk, 2010/2011; Vol 6(4): 1-37.

Wilhelmsen, Mathilde; Dimakos, Xeni K.; Husebø, Tore A.; Fiskaaen, Marit: Bayesian modelling of credit risk using Integrated Nested Laplace Approximations. In: Rethinking Risk

Management and Reporting: Measurement, Uncertainty, Bayesian Analysis and Expert Judgement, Risk Books, London, 2010.

Technical reports:

Aas, Kjersti: Validering av modell for finansielle indikatorer. NR-Note, SAMBA/25/09, 2009.

Aas, Kjersti: Sammenligning av metoder for risikoaggregering. NR-Note, SAMBA/06/11, 2011.

Aas, K. Estimating market risk based on historical data. NR-Note, SAMBA/37/12, 2012.

Aas, K; Haff, IH. DNB Total Risk Model Version 4: Technical report. NR-Note, SAMBA/04/12, 2012.

Aas, K; Holden, M. Importance Sampling from DNB's Credit Risk Model. NR-Note, SAMBA/31/12, 2012.

Cui, SY; Aas, K. CIR++-rentemodellen. NR-Note, SAMBA/34/12, 2012.

Hobæk Haff, Ingrid; Vårdal, Jofrid; Aas, Kjersti: Modellering av finansielle indikatorer. NR-Note, SAMBA/48/08, 2008.

Holden, Lars; Haug, Ola: A Multidimensional Mixture Model for Unsupervised Tail Estimation, Technical Note, 2010.

Holden, Marit; Aas, Kjersti: Parallellisering av Totalrisiko-programmet. NR-Note, SAMBA/43/10, 2010.

Holden, Marit; Aas, Kjersti: Parallellisering av Totalrisiko-programmet ved hjelp av GPU. NR-Note SAMBA13/11, 2011.

Holden, Marit; Aas, Kjersti: Parallellisering av simulering fra vines. NR-Note, SAMBA/18/11,2011.

Løland, Anders: Justering til gyldig korrelasjonsmatrise. NR-Note, SAMBA/11/08, 2008.

Ministry of Environment, Oslo. Seminar on the effect of climate change