

Hager, Svenja; Schöbel, Rainer

Working Paper

Deriving the dependence structure of portfolio credit derivatives using evolutionary algorithms

Tübinger Diskussionsbeiträge, No. 300

Provided in Cooperation with:

University of Tuebingen, Faculty of Economics and Social Sciences, School of Business and Economics

Suggested Citation: Hager, Svenja; Schöbel, Rainer (2006) : Deriving the dependence structure of portfolio credit derivatives using evolutionary algorithms, Tübinger Diskussionsbeiträge, No. 300, Eberhard Karls Universität Tübingen, Wirtschaftswissenschaftliche Fakultät, Tübingen, <https://nbn-resolving.de/urn:nbn:de:bsz:21-opus-21859>

This Version is available at:

<https://hdl.handle.net/10419/40319>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Wirtschaftswissenschaftliche Fakultät
der Eberhard-Karls-Universität Tübingen

**Deriving the Dependence Structure
of Portfolio Credit Derivatives
Using Evolutionary Algorithms**

Svenja Hager
Rainer Schöbel

Tübinger Diskussionsbeitrag Nr. 300
Februar 2006

Wirtschaftswissenschaftliches Seminar
Mohlstraße 36, D-72074 Tübingen

Deriving the Dependence Structure of Portfolio Credit Derivatives Using Evolutionary Algorithms

Svenja Hager and Rainer Schöbel *

Abstract

Even if the correct modeling of default dependence is essential for the valuation of portfolio credit derivatives, for the pricing of synthetic CDOs a one-factor Gaussian copula model with constant and equal pairwise correlations for all assets in the reference portfolio has become the standard market model. If this model were a reflection of market opinion, there wouldn't be the implied correlation smile that is observed in the market. The purpose of this paper is to derive a correlation structure from observed CDO tranche spreads. The correlation structure is chosen such that all tranche spreads of the traded CDO can be reproduced. This implied correlation structure can then be used to price off-market tranches with the same underlying as the traded CDO. Using this approach we can significantly reduce the risk to misprice off-market derivatives. Due to the complexity of the optimization problem we apply Evolutionary Algorithms.

1 Introduction

Although it is still of interest to find empirical sources of correlation data, people increasingly use the market of synthetic collateralized debt obligations (CDOs) to derive information about the correlation structure of the underlying of a CDO. An observed CDO premium can be interpreted as an indicator of asset correlation. Therefore, more and more tranching products are quoted in terms of an implied correlation parameter instead of the spread or the price of a tranche. The implied correlation of a tranche is the uniform asset correlation that makes the tranche spread computed by the standard market model equal to its observed market spread. The standard market model is a Gaussian copula model that uses only one single parameter to summarize all correlations among the various borrowers' default times. But obviously, a flat correlation structure is not able to reflect the heterogeneity of the underlying asset correlations since the complex relationship between the default times of different assets can't be expressed in one single number. Apparently, the standard market model doesn't reflect market opinion because the implied correlation smile emerges. Mezzanine tranches typically trade at lower implied correlations than equity and senior tranches on the same portfolio. This phenomenon is called implied correlation smile. Despite the questionable explanatory power of the implied correlation parameter, the implied correlation

*Department of Corporate Finance, Faculty of Economics and Business Administration, Eberhard-Karls-University of Tübingen, Mohlstraße 36, 72074 Tübingen, Germany, Phone: +49-7071-29-78214 or -77088, E-Mail: {svenja.hager;rainer.schoebel}@uni-tuebingen.de

of a CDO tranche is often used to price off-market products with the same underlying as the traded CDO.

Recently, more and more researchers examine different approaches to explain and model the correlation smile. Gregory and Laurent [2] and Andersen and Sidenius [1] introduce dependence between recovery rates and defaults. In a second extension Andersen and Sidenius use random factor loadings to permit higher correlation in economic depressions. Both approaches are able to model a smile. Hull and White discuss the effect of uncertain recoveries on the specification of the smile [4].

The correlation smile shows clearly that it is not appropriate to use the implied correlation of a traded CDO tranche to value non-standard tranches on the same collateral pool. To address these shortcomings we take the implied correlation approach one step further and imply a correlation matrix that reproduces all given tranche spreads of a CDO simultaneously. The dependence structure is chosen such that the resulting tranche prices are concordant with observed market prices or, respectively, such that the observed correlation smile is reproduced. Hager and Schöbel show in [3] that heterogeneous correlation structures are able to model a smile. After we derived a suitable asset correlation structure, we can use this dependency to price off-market products with the same underlying. In this study we use Evolutionary Algorithms (EAs) to derive a dependence structure from observed CDO tranche spreads. We show systematically why EAs are suitable for this kind of application. So far, there is only a limited amount of studies that connect EAs with derivative pricing. To our knowledge we are the first to apply EAs to the implied correlation problem and we are the first to derive a correlation matrix that is not necessarily flat from a set of observed tranche spreads.

2 The Optimization Problem

Suppose for the moment that we know the tranche spreads of an actively traded CDO. We assume that the CDO consists of an equity tranche, a mezzanine tranche and a senior tranche. Our goal is to derive a correlation matrix Σ that replicates the given tranche spreads of the equity, the mezzanine and the senior tranche simultaneously. Denote these target values as $\overline{s_e}$, $\overline{s_m}$ and $\overline{s_s}$. It is intuitively clear that in general there can be more than one correlation matrix that leads to the respective tranche spreads $\overline{s_e}$, $\overline{s_m}$ and $\overline{s_s}$ (see Hager and Schöbel [3]). Note that there might also be combinations of tranche spreads that can't be reproduced by any correlation matrix. However, there is no way to derive the correlation matrix Σ in closed form since even the portfolio loss distribution can't be computed in closed form for arbitrary correlation matrices.

To measure the quality of an obtained correlation matrix Σ , we first compute the appendant equity, mezzanine and senior tranche spreads $s_e(\Sigma)$, $s_m(\Sigma)$ and $s_s(\Sigma)$ and compare them with the given target values $\overline{s_e}$, $\overline{s_m}$ and $\overline{s_s}$. The goal is to find a correlation matrix such that the corresponding spreads agree. The optimization problem discussed in this study is rather complex because the search space is high dimensional and multi-modal and the objective function is non-linear, non-differentiable and discontinuous. Note that for arbitrary correlation matrices often both $s_e(\Sigma)$, $s_m(\Sigma)$, $s_s(\Sigma)$

and $\overline{s_e}$, $\overline{s_m}$, $\overline{s_s}$ are obtained via Monte-Carlo simulation. In this case we have to deal with noise. Since our optimization problem is characterized by these properties, the number of applicable optimization techniques is restricted. We choose EAs to address this problem. EAs are stochastic search methods that are inspired by the Darwinian theory. They model the collective learning process within a population. The starting population is generally initialized by random. In the course of the generations the population is supposed to evolve toward successively better regions of the search space by randomized processes of selection, recombination and mutation. The generations are searched until a sufficiently good solution is found or until a termination criterion is met. Similar to other heuristic search methods, it is not guaranteed that EAs find the global optimum, but they generally find good solutions in a reasonable amount of time.

Consider the function $f(\Sigma)$ which measures the sum of the relative absolute deviations of the obtained tranche spreads from the target spreads:

$$f(\Sigma) = \frac{|s_e(\Sigma) - \overline{s_e}|}{\overline{s_e}} + \frac{|s_m(\Sigma) - \overline{s_m}|}{\overline{s_m}} + \frac{|s_s(\Sigma) - \overline{s_s}|}{\overline{s_s}} .$$

In our optimization problem low values of $f(\Sigma)$ stand for high quality. In a population based optimization strategy with λ individuals, we neglect the overall performance of a certain generation and just consider the best individual in the respective generation. The objective function registers the quality of the best individual that has been generated so far. Let $h(t)$ denote the objective function at time t and let $\Sigma^{k,\tau}$ denote the k^{th} individual in generation τ , $k \in \{1, \dots, \lambda\}$, $\tau \in \{1, \dots, t\}$. Consequently, the objective function, that has to be minimized, is

$$h(t) = \min_{k \in \{1, \dots, \lambda\}, \tau \in \{1, \dots, t\}} (f(\Sigma^{k,\tau})) .$$

3 Pricing of Synthetic CDOs

In this study we always assume that the intensity based approach describes the default of one obligor and that the Gaussian copula model with an arbitrary correlation matrix describes the dependency between the obligors' default times. In our optimization problem all model parameters are known except for the pairwise linear correlations.

Following Laurent and Gregory [5] we consider a synthetic CDO, whose underlying consists of n reference assets, and assume that asset j has exposure $\frac{1}{n}$ and default time τ_j . $N_j(t) = 1_{\{\tau_j \leq t\}}$ denotes the default indicator process. The cumulative portfolio loss at time t is therefore $L(t) = \frac{1}{n} \sum_{j=1}^n N_j(t)$. A CDO is a structured product that can be divided into various tranches. The cumulative default of tranche (A, B) , $0 \leq A < B \leq 1$ is the non-decreasing function

$$\omega(L(t)) = (L(t) - A)1_{[A,B]}(L(t)) + (B - A)1_{[B,1]}(L(t)) .$$

The tranche spread $s_{(A,B)}$ depends on the thresholds A and B . Let $B(t)$ be the discount factor for maturity t . T stands for the maturity of the CDO and let $t_1, \dots, t_I$ denote the regular payment dates for the CDO margins.

The *default payments* can be written as

$$E \left[\sum_{j=1}^n B(\tau_j) N_j(T) (\omega(L(\tau_j)) - \omega(L(\tau_j^-))) \right]. \quad (1)$$

The *margin payments* are based on the outstanding nominal of the tranche. Since defaults often take place between regular payment dates we have to distinguish between the *regular payments*

$$s_{(A,B)} \sum_{i=1}^I B(t_i) E [B - A - \omega(L(t_i))] \quad (2)$$

and the *accrued payments*. Accrued margins are paid for the time from the last regular payment date before τ_j (this date is called $t_{k(j)-1}$) until τ_j . The *accrued payments* can be written as

$$s_{(A,B)} E \left[\sum_{j=1}^n B(\tau_j) N_j(T) (\tau_j - t_{k(j)-1}) (\omega(L(\tau_j)) - \omega(L(\tau_j^-))) \right]. \quad (3)$$

A synthetic CDO can be compared with a default swap transaction because the CDO margin payments are exchanged with the default payments on the tranche. The spread $s_{(A,B)}$ is derived by setting the margin payments in (2) and (3) and the default payments in (1) equal.

4 Experimental Settings and Results

4.1 Description of the Genotype

Correlation matrices are symmetric positive semi-definite matrices whose matrix elements are in $[-1, 1]$. The diagonal of a correlation matrix always consists of ones. In the following, $\Sigma = (\Sigma_{ij})_{i,j=1,\dots,n}$ denotes the correlation matrix. We use Σ as phenotype and a row vector $\rho = (\rho_i)_{i=1,\dots,n} \in [-1, 1]^n$ as real-valued genotype. The pairwise linear correlation between asset i and asset j can be computed as $\Sigma_{ij} = \rho_i \rho_j$, $i \neq j$ and $\Sigma_{ij} = 1$, $i = j$. Using this so-called one-factor approach we can avoid Monte-Carlo simulations and provide semi-explicit expressions for CDO tranche spreads (see Laurent and Gregory [5]). Note that there are correlation matrices that can't be represented by the one-factor approach.

The initial population consists of randomly generated vectors $\rho \in [-1, 1]^n$. An arbitrary vector ρ automatically leads to a symmetric, positive semi-definite matrix with elements $\Sigma_{ij} = \rho_i \rho_j$, $i \neq j$ and $\Sigma_{ij} = 1$, $i = j$.

In this study we compare several standard recombination and mutation schemes. They are carried out according to custom.

Note that recombination and mutation can breed vector elements with $|\rho_i| > 1$.

To make sure that the pairwise correlations are in $[-1, 1]$, define a censored vector $\rho^* = (\rho_i^*)_{i=1, \dots, n}$ with $\rho_i^* = \min(\max(\rho_i, -1), 1)$ that replaces ρ . We maintain this modified representation of the genotype.

We consider two cases of suitable termination conditions. Naturally, reaching the optimum of the objective function with a certain precision should be used as stopping condition. Therefore, we stop our algorithm as soon as the objective function falls below a predefined value. Furthermore, we terminate the EA when the total number of function evaluations reaches a given limit.

4.2 Setup

To assess the potential of our approach, we work with simulated data. We compare the performance of a Monte-Carlo Search, a Hill-Climber $((1 + 1)\text{-ES})$, an Evolution Strategy with 4 parent and 20 offspring individuals $((4, 20)\text{-ES})$ and a generational Genetic Algorithm with 40 individuals $(\text{GA}(40))$. We mutate individuals by adding realizations of normally distributed random variables with expected value 0 and standard deviation 0.05 unless explicitly mentioned otherwise. We apply global mutation operators, i.e. every vector element is subject to mutation. In case of the $(4, 20)\text{-ES}$ we use elite selection and 1-point crossover. Our focus is on the application of different mutation operators. We consider the $1/5$ -rule, global mutation without a strategy parameter and global mutation with a strategy parameter that controls the mutation step size. The mutation probability is 0.95, the crossover probability is 0.50. In case of the $\text{GA}(40)$ we focus on the selection and crossover parameters. We use proportional selection and tournament selection with a tournament group size of 10. We use 1-point crossover and intermediate crossover and we use global mutation without a strategy parameter. The crossover probability is 0.95, the mutation probability is 0.50. For the sake of simplicity we just consider non-negative pairwise linear correlations and therefore non-negative genotypes. As soon as the objective function falls below 5% we terminate the algorithm. At most 2000 function evaluations are carried out.

We consider a CDO that consists of three tranches. The respective attachment and detachment levels are 0%-5%, 5%-15%, 15%-100%. We assume that the underlying is a homogeneous pool of 10 names with equal unit nominal. The default intensity of each obligor is 1%, the recovery rate is 40%. The time to maturity is 5 years.

Our goal is to find a correlation matrix that models an observed compound correlation smile. The given implied compound correlations are 0.24 for the equity tranche, 0.05 for the mezzanine tranche and 0.35 for the senior tranche. At first, we compute the spreads of the equity, the mezzanine and the senior tranche using the respective implied correlations. We get 802.2 bps (basis points), 204.4 bps and 9.0 bps. Then, we have to find a correlation matrix that reproduces all three tranche spreads simultaneously.

4.3 Performance

To make sure that we obtain reliable results, we repeat each implementation 25 times. We compute the mean value of the objective functions over the 25 runs, and we also

consider the 10% and the 90% quantiles. Our focus is on the decline of the objective function in the course of the generations. To compare the performance of the different algorithms consider figure 1. It shows the average values of the objective functions for the different implementations.

At first we compare a Monte-Carlo search and a $(1 + 1)$ -ES to analyze the search space. Generally, the Monte-Carlo search is rather inefficient especially in high dimensional search spaces. Whenever the Monte-Carlo search performs as well as a Hill-Climber or a population-based EA, the search space is probably very flat or very cragged or non-causal. However, in our case the Hill-Climbing strategy clearly outperforms the random search. Often, $(1 + 1)$ -strategies are very efficient in simple unimodal search spaces. But if a Hill-Climber starts up the wrong hill, it has no chance to know that it has found an inferior optimal solution. Therefore, Hill-Climbing strategies frequently can't handle situations in which there are several local optima.

Then we extend the $(1 + 1)$ -ES to a multistart $(1 + 1)$ -ES. A multistart $(1 + 1)$ -ES reduces the risk of premature convergence. We obtain several different solution matrices (see figure 2 for two examples). These matrices yield tranche spreads that are sufficiently close to 802.2 bps, 204.4 bps and 9.0 bps, i.e. the sum of the percentual deviations is less than 5%. This leads to the conclusion that the search space is multimodal.

We now compare different implementations of a $(4, 20)$ -ES and a GA(40). The performance of the different ES implementations is nearly identic, the confidence intervals widely overlap. There is only a very small difference, but the global mutation strategy with one strategy parameter outperforms the other approaches. Then we compare the different GA implementations. The performance of the different GA implementations differs considerably. The GA with tournament selection combined with 1-point crossover leads to the best result. The GA with proportional selection and 1-point crossover performs moderately. The GA with proportional selection and intermediate crossover converges too fast to a dissatisfactory solution. This implementation yields the worst result. Note that by means of recombination the hyperbody formed by the parents generally can't be left by the offspring individuals. Especially the intermediate crossover technique causes volume reduction, since it successively narrows the search space, such that eventually the optimal solution can't be attained any more after a few generations.

We finally compare all algorithms on the basis of function evaluations needed to obtain a sufficiently good result. The $(1 + 1)$ -ES performs slightly better than the $(4, 20)$ -ES implementations, there is only a very small difference. However, the GA implementation can't keep up with the ES implementations.

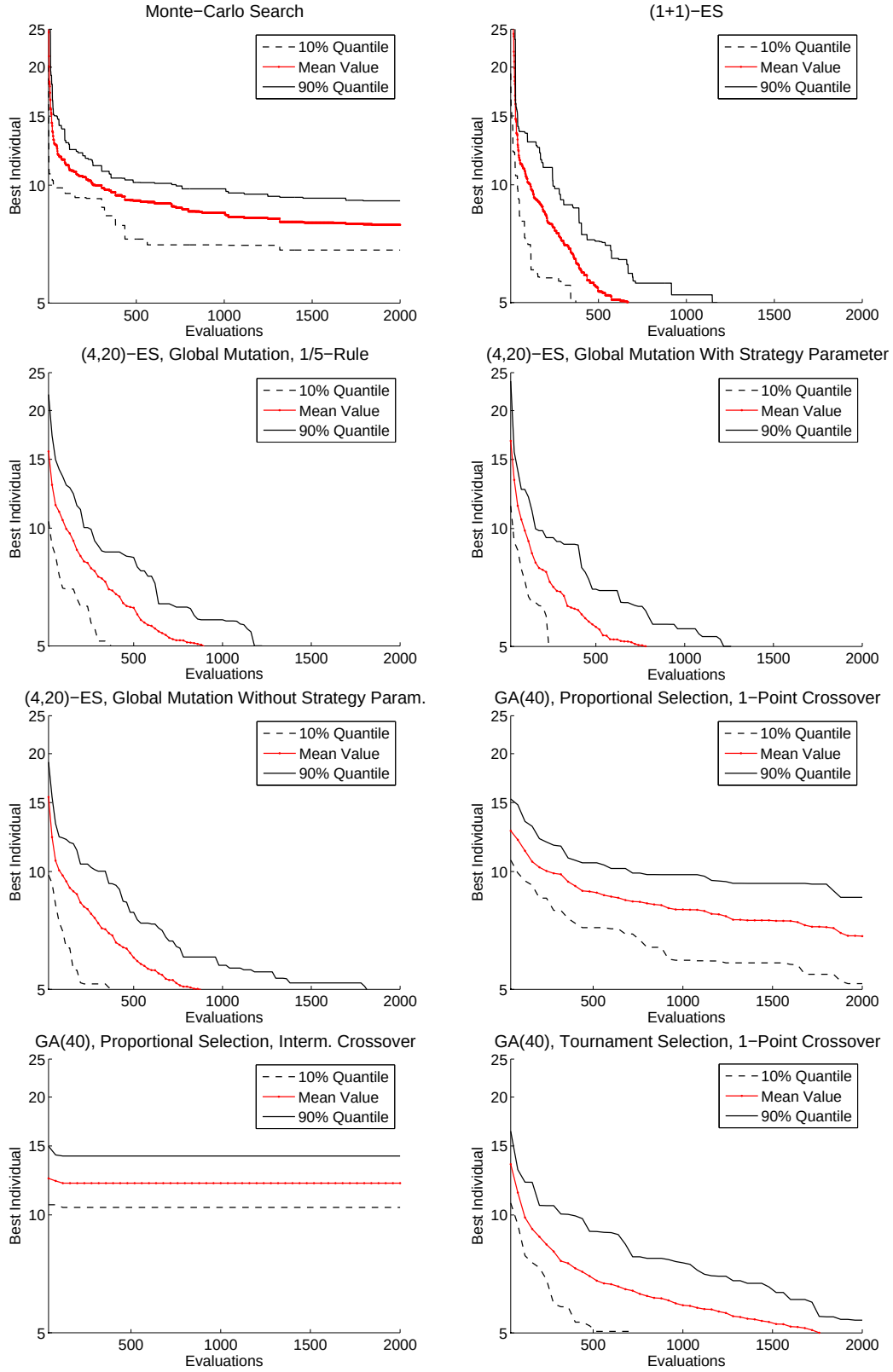


Fig.1. Performance of different algorithms

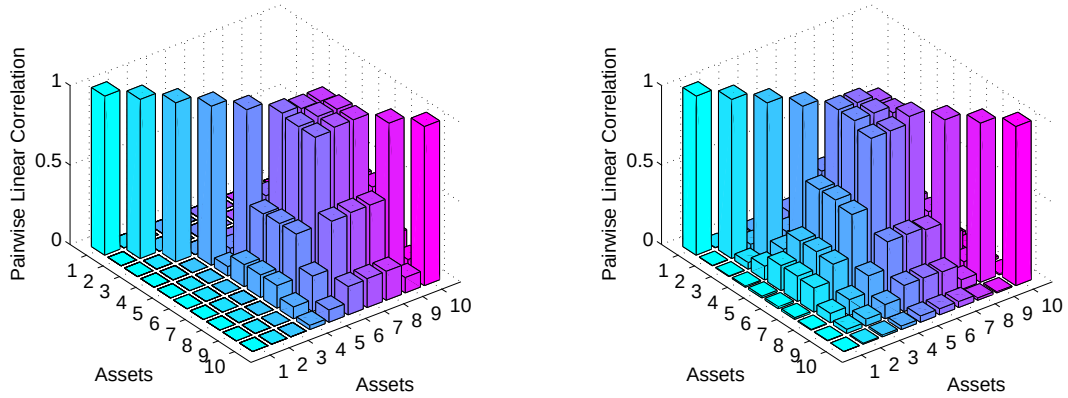


Fig.2. Exemplary correlation matrices

5 Conclusion

In this study we used the concept of Evolutionary Algorithms to derive possible correlation structures of the underlying of a traded CDO from observed tranche spreads. These dependence structures can then be used to price off-market products with the same underlying as the CDO. Using this strategy we can reduce the pricing discrepancy that comes up when the implied correlation approach is applied. We presented several implementations of Evolutionary Algorithms and discussed their performance.

References

- [1] Andersen, L., Sidenius, J.: Extensions to the Gaussian copula: Random recovery and random factor loadings. *The Journal of Credit Risk* **1**(1) (2004) 29-70
- [2] Gregory, J., Laurent, J.P.: In the core of correlation. *Risk*, October (2004) 87-91
- [3] Hager, S., Schöbel R.: A note on the correlation smile. *Tübinger Diskussionsbeitrag* **297** (2005)
- [4] Hull, J., White, A.: Valuation of a CDO and an n^{th} to default CDS without Monte-Carlo simulation. *The Journal of Derivatives* **12**(2) (2004) 8-23
- [5] Laurent, J.P., Gregory, J.: Basket default swaps, CDOs and factor copulas. *The Journal of Risk* **7**(4) (2005) 103-122

Die Liste der hier aufgeführten Diskussionsbeiträge beginnt mit der Nummer 228 im Jahr 2002. Die Texte können direkt aus dem Internet bezogen werden. Sollte ein Interesse an früher erschienenen Diskussionsbeiträgen bestehen, kann die vollständige Liste im Internet eingesehen werden. Die Volltexte der dort bis Nummer 144 aufgeführten Diskussionsbeiträge können nur direkt über die Autoren angefordert werden.

228. **Starbatty, Joachim:** Röpkes Beitrag zur Sozialen Marktwirtschaft, Januar 2002.
229. **Nufer, Gerd:** Bestimmung und Analyse der Erfolgsfaktoren von Marketing-Events anhand des Beispiels DFB-adidas-Cup, März 2002.
230. **Schnabl, Gunther:** Asymmetry in US-Japanese Foreign Exchange Policy: Shifting the Adjustment Burden to Japan, März 2002.
231. **Gampfer, Ralf:** Fallende Preise in Sequentiellen Auktionen: Das Beispiel des Gebrauchtwagenhandels, März 2002.
232. **Baur, Dirk:** The Persistence and Asymmetry of Time-Varying Correlations, März 2002.
233. **Bachmann, Mark:** Ermittlung und Relevanz effektiver Steuersätze. Teil 1: Anwendungsbereich und Modellerweiterungen, März 2002.
234. **Knirsch, Deborah:** Ermittlung und Relevanz effektiver Steuersätze. Teil 2: Der Einfluss der Komplexitätsreduktion von Steuerbemessungsgrundlagen, März 2002.
235. **Neubecker, Leslie:** Aktienkursorientierte Managemententlohnung bei korrelierter Entwicklung der Marktnachfrage, März 2002.
236. **Kukuk, Martin und Manfred Stadler:** Rivalry and Innovation Races, März 2002.
237. **Stadler, Manfred:** Leistungsorientierte Besoldung von Hochschullehrern auf der Grundlage objektiv meßbarer Kriterien?, März 2002.
238. **Eisele, Florian, Habermann, Markus und Ralf Oesterle:** Die Beteiligungskriterien für eine Venture Capital Finanzierung – Eine empirische Analyse der phasenbezogenen Bedeutung, März 2002.
239. **Niemann, Rainer und Dirk Kiesewetter:** Zur steuerlichen Vorteilhaftigkeit von Kapitallebensversicherungen, März 2002.
240. **Hornig, Stephan:** Information Exchange with Cost Uncertainty: An Alternative Approach with New Results, Februar 2004.
241. **Niemann, Rainer, Bachmann, Mark und Deborah Knirsch:** Was leisten die Effektivsteuersätze des European Tax Analyzer?, Juni 2002.
242. **Kiesewetter, Dirk:** Tax Neutrality and Business Taxation in Russia: A Proposal for a Consumption-Based Reform of the Russian Income and Profit Tax, Juni 2002.
243. **McKinnon, Ronald und Gunther Schnabl:** Synchronized Business Cycles in East Asia and Fluctuations in the Yen/Dollar Exchange Rate, Juli 2002.
244. **Neus, Werner:** Fusionsanreize, strategische Managerentlohnung und die Frage des geeigneten Unternehmensziels, Juli 2002.
245. **Blüml, Björn und Werner Neus:** Grenzüberschreitende Schuldverträge und Souveränitätsrisiken, Juli 2002.
246. **Starbatty, Joachim:** Die Abschaffung der DM ist noch keine Bereitschaft zur politischen Union, Juli 2002.
247. **Schnabl, Gunther:** Fear of Floating in Japan? A Bank of Japan Monetary Policy Reaction Function, September 2002.
248. **Brassat, Marcel und Dirk Kiesewetter:** Steuervorteile durch Versorgungszusagen in Arbeitsverträgen, September 2002.
249. **Knirsch, Deborah:** Neutrality-Based Effective Tax Rates, September 2002.

250. **Neubecker, Leslie:** The Strategic Effect of Debt in Dynamic Price Competition with Fluctuating Demand, November 2002.
251. **Baur, Dirk und Robert Jung:** Return an Volatility Linkages Between the US and the German Stock Market, Dezember 2002.
252. **McKinnon, Ronald und Gunther Schnabl:** The East Asian Dollar Standard, Fear of Floating, and Original Sin, Januar 2003.
253. **Schulze, Niels und Dirk Baur:** Coexceedances in Financial Markets – A Quantile Regression Analysis of Contagion, Februar 2003.
254. **Bayer, Stefan:** Possibilities and Limitations of Economically Valuating Ecological Damages, Februar 2003.
255. **Stadler, Manfred:** Innovation and Growth: The Role of Labor-Force Qualification, März 2003.
256. **Licht, Georg und Manfred Stadler:** Auswirkungen öffentlicher Forschungsförderung auf die private F&E-Tätigkeit: Eine mikroökonometrische Evaluation, März 2003.
257. **Neubecker, Leslie und Manfred Stadler:** Endogenous Merger Formation in Asymmetric Markets: A Reformulation, März 2003.
258. **Neubecker, Leslie und Manfred Stadler:** In Hunt for Size: Merger Formation in the Oil Industry, März 2003.
259. **Niemann, Rainer:** Wie schädlich ist die Mindestbesteuerung? Steuerparadoxa in der Verlustverrechnung, April 2003.
- 260.
261. **Neubecker, Leslie:** Does Cooperation in Manufacturing Foster Tacit Collusion?, Juni 2003.
262. **Buchmüller, Patrik und Christian Macht:** Wahlrechte von Banken und Aufsicht bei der Umsetzung von Basel II, Juni 2003.
263. **McKinnon, Ronald und Gunther Schnabl:** China: A Stabilizing or Deflationary Influence in East Asia? The Problem of Conflicted Virtue, Juni 2003.
264. **Thaut, Michael:** Die individuelle Vorteilhaftigkeit der privaten Rentenversicherung – Steuervorteile, Lebenserwartung und Stornorisiken, Juli 2003.
265. **Köpke, Nikola und Jörg Baten:** The Biological Standard of Living in Europe During the Last Two Millennia, September 2003.
266. **Baur, Dirk, Saisana, Michaela und Niels Schulze:** Modelling the Effects of Meteorological Variables on Ozone Concentration – A Quantile Regression Approach, September 2003.
267. **Buchmüller, Patrik und Andreas Marte:** Paradigmenwechsel der EU-Finanzpolitik? Der Stabilitätspakt auf dem Prüfstand, September 2003.
268. **Baten, Jörg und Jacek Wallusch:** Market Integration and Disintegration of Poland and Germany in the 18th Century, September 2003.
269. **Schnabl, Gunther:** De jure versus de facto Exchange Rate Stabilization in Central and Eastern Europe, Oktober 2003.
270. **Bayer, Stefan:** Ökosteuern: Versöhnung von Ökonomie und Ökologie?, Oktober 2003.
271. **Köhler, Horst:** Orientierungen für eine bessere Globalisierung, November 2003.
272. **Lengsfeld, Stephan und Ulf Schiller:** Transfer Pricing Based on Actual versus Standard Costs, November 2003.
273. **Lengsfeld, Stephan und Thomas Vogt:** Anreizwirkungen kostenbasierter Verrechnungspreise bei externen Effekten –Istkosten– versus standardkostenbasierte Verrechnungspreise bei Kreuzinvestitionen -, November 2003.
274. **Eisele, Florian und Andreas Walter:** Kurswertreaktionen auf die Ankündigung von Going Private-Transaktionen am deutschen Kapitalmarkt, Dezember 2003.
275. **Rall, Wilhelm:** Unternehmensstrategie für den globalen Wettbewerb, Februar 2004.
276. **Niemann, Rainer:** Entscheidungswirkungen von Verlustverrechnungsbeschränkungen bei der Steuerplanung grenzüberschreitender Investitionen, Februar 2004.

277. **Kirchner, Armin:** Verringerung von Arbeitslosigkeit durch Lockerung des Kündigungsschutzes – Die entscheidende Einflussgröße, März 2004.
278. **Kiesewetter, Dirk und Andreas Lachmund:** Wirkungen einer Abgeltungssteuer auf Investitionsentscheidungen und Kapitalstruktur von Unternehmen, April 2004
279. **Schanz, Sebastian:** Die Auswirkungen alternativer Gewinnverwendung von Kapitalgesellschaften im Rahmen des Halbeinkünfteverfahrens auf die Vermögenspositionen Residualanspruchsberechtigter, Mai 2004.
280. **Stadler, Manfred:** Bildung, Innovationsdynamik und Produktivitätswachstum, Mai 2004.
281. **Grupp, Hariolf und Manfred Stadler:** Technological Progress and Market Growth. An Empirical Assessment Based on the Quality Ladder Approach, Mai 2004.
282. **Güth, Werner und Manfred Stadler:** Path Dependence without Denying Deliberation. An Exercise Model Connecting Rationality and Evolution, Mai 2004.
283. **Duijm, Bernhard:** Offener Regionalismus als pareto-verbessernde Integrationsform, Juni 2004.
284. **Pitterle, Ingo und Dirk Steffen:** Welfare Effects of Fiscal Policy under Alternative Exchange Rate Regimes: The Role of the Scale Variable of Money Demand, Juni 2004.
285. **Molzahn, Alexander:** Optimale Fiskalpolitik und endogenes Wachstum, Juli 2004.
286. **Jung, Robert, Kukuk, Martin und Roman Liesenfeld:** Time Series of Count Data: Modelling and Estimation, August 2004.
287. **De Grauwe, Paul und Gunther Schnabl:** Nominal versus Real Convergence with Respect to EMU Accession. EMU Entry Scenarios for the New Member States, August 2004.
288. **Kleinert, Jörn und Farid Toubal:** A Structural Model of Exports versus Production Abroad, Dezember 2004.
289. **Godart, Olivier und Farid Toubal:** Cross the Border and Close the Gap? How do Migrants Enhance Trade, Januar 2005.
290. **Schnabl, Gunther und Christian Danne:** The Changing Role of the Yen/Dollar Exchange Rate for Japanese Monetary Policy, Februar 2005.
291. **Schnabl, Gunther:** Der Festkurs als merkantilistische Handelspolitik – Chinas Währungs- und Geldpolitik im Umfeld globaler Ungleichgewichte, Februar 2005.
292. **Starbatty, Joachim:** Anmerkungen zum Woher und Wohin der Europäischen Union, Februar 2005.
293. **Wagner, Franz W.:** Steuervereinfachung und Entscheidungsneutralität - konkurrierende oder komplementäre Leitbilder für Steuerreformen?, April 2005.
294. **Yu, Peiyi und Werner Neus:** Market Structure, Scale Efficiency, and Risk as Determinants of German Banking Profitability, Juni 2005.
295. **Schüle, Tobias und Manfred Stadler:** Signalling Effects of a Large Player in a Global Game of Creditor Coordination, Juni 2005.
296. **Zaby, Alexandra:** Losing the Lead: Patents and the Disclosure Requirement, August 2005.
297. **Hager, Svenja und Rainer Schöbel:** A Note on the Correlation Smile, Dezember 2005.
298. **Starbatty, Joachim:** Zum Zusammenhang von Politik, Ethik und Ökonomik bei Aristoteles, Dezember 2005.
299. **Rostek, Stefan und Rainer Schöbel:** Risk Preference Based Option Pricing in a Fractional Brownian Market, Januar 2006.
300. **Hager, Svenja und Rainer Schöbel:** Deriving the Dependence Structure of Portfolio Credit Derivatives Using Evolutionary Algorithms, Februar 2006.