

Studienreihe der Stiftung Kreditwirtschaft
an der Universität Hohenheim

Jan Müller

**Optimal Economic Capital Allocation
in Banking on the Basis of
Decision Rights**



Verlag Wissenschaft & Praxis



Optimal Economic Capital Allocation in Banking
on the Basis of Decision Rights

**Studienreihe der Stiftung Kreditwirtschaft
an der Universität Hohenheim**

Herausgeber:

Prof. Dr. Hans-Peter Burghof

Band 52

Jan Müller

**Optimal Economic Capital Allocation
in Banking on the Basis of
Decision Rights**

Verlag Wissenschaft & Praxis



Bibliografische Information der Deutschen Nationalbibliothek

Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über <http://dnb.dnb.de> abrufbar.

D100

ISBN 978-3-89673-707-6

© Verlag Wissenschaft & Praxis

Dr. Brauner GmbH 2015

D-75447 Sternenfels, Nußbaumweg 6

Tel. +49 7045 930093 Fax +49 7045 930094

verlagwp@t-online.de www.verlagwp.de

Alle Rechte vorbehalten

Das Werk einschließlich aller seiner Teile ist urheberrechtlich geschützt. Jede Verwertung außerhalb der engen Grenzen des Urheberrechtsgesetzes ist ohne Zustimmung des Verlages unzulässig und strafbar. Das gilt insbesondere für Vervielfältigungen, Übersetzungen, Mikroverfilmungen und die Einspeicherung und Verarbeitung in elektronischen Systemen.

Druck und Bindung: Esser printSolutions GmbH, Bretten

FOREWORD

The Studienreihe Stiftung Kreditwirtschaft aims at offering banking and finance subjects from the University of Hohenheim's research to interested expert readers. The publications are meant to promote the exchange of ideas between University and practice.

The banking regulation today forces to provide more economic capital in order to increase the ability of banks to cover unexpected losses on their own, to guarantee their going concern and prevent bankruptcy with a high probability. In this context, banks regularly choose their existing overall portfolio as a starting point in order to determine their economic capital requirements.

However, a strict risk-return-management perspective suggests the reverse procedure. In this case the available economic capital represents the starting point. The capital then undergoes an allocation among the bank's business fields while maintaining a certain confidence level and maximizing the bank's overall expected return. Finally, this procedure determines the business fields' business volumes and thereby induces an overall bank management according to risk-return aspects.

Neither research nor practice so far provide clear and preferential overall bank management approaches of that type. This might be caused by the underlying problem's comprehensiveness that immediately arises if the problem's consideration correctly and necessarily applies a portfolio theoretical perspective. However, the pressure of the surging equity requirements on Banks' profitability after the financial crises even increases the need for such integral overall bank management systems.

The present work emphasizes the crucial points to be addressed in context with an optimal economic capital allocation. In doing so, the focus lies on the immanently important consideration of decision makers and their autonomous decision making's implications. The work makes a valuable contribution to the understanding of the struggles banks face today on the field of overall bank management driven by a changing economic and regulatory environment.

This volume represents a further contribution to our successful promotion of exchanging ideas between University and practice in highly relevant fields from banking and finance.

Hohenheim, June 2015

Prof. Dr. Hans-Peter Burghof

CONTENTS

FIGURES	11
TABLES	15
ALGORITHMS	17
1 INTRODUCTION	19
1.1 Problem and research question	19
1.2 Organization of the research	21
2 CORPORATE MANAGEMENT BY ECONOMIC CAPITAL ALLOCATION.....	25
2.1 Properties of economic capital.....	25
2.2 Required economic capital by downside risk measurement.....	26
2.3 Corporate management by bank-wide VAR limit systems	28
2.4 Economic capital allocation on the basis of risk adjusted performance measurement.....	31
2.4.1 Introduction to risk adjusted Performance measures.....	31
2.4.2 Controversial benchmarking on the basis of hurdle rates.....	32
2.4.3 Implications of limit addressees in the form of decision makers ...	33
2.5 Economic capital allocation as a situation of delegation by decision rights	34
2.5.1 Implications for the risk management process	34
2.5.2 Costs of delegation by decision rights.....	36
3 IMPLICATIONS OF RELATED FIELDS OF RESEARCH	41
3.1 Different situations of economic capital allocation	41
3.2 Risk contribution – a form of economic capital allocation.....	42
3.2.1 Risk contribution schemes.....	42
3.2.2 Particular approaches from the field of risk contribution.....	44
3.3 Axiomatization of economic capital allocation	46
3.3.1 Axiomatization of risk measures	46

3.3.2	Transfer of the axiomatization framework to economic capital allocation	48
3.4	Risk assessment over time by dynamic risk measures	50
3.5	Economic capital allocation as a means of corporate management.....	53
3.6	Portfolio optimization under a downside risk constraint	60
3.6.1	Approaches on the basis of traditional methods of optimization....	60
3.6.2	Heuristic methods of optimization.....	62
3.6.2.1	Categorization of the field of heuristic optimization	62
3.6.2.2	Approaches on the basis of heuristic optimization methods.....	64
4	BASIC MODEL OF OPTIMAL ECONOMIC CAPITAL ALLOCATION.....	69
4.1	Qualitative description of the model.....	69
4.2	Determination of the underlying stochastic program	71
4.3	Valuation of the objective function on the basis of a trading simulation	74
4.3.1	Simulation of the stocks' returns	74
4.3.2	Simulation of the business units' profits and losses	76
4.3.3	Simulation of the heterogeneous prospects of success of the business units.....	78
4.4	Out-of-sample backtesting and the role of importance sampling	80
5	HEURISTIC OPTIMIZATION OF RISK LIMIT SYSTEMS BY THRESHOLD ACCEPTING	83
5.1	Visual proof of non-convexity by an exemplary model case	83
5.2	Basic algorithm of threshold accepting	87
5.3	Determination of start solutions.....	89
5.4	Neighborhood function.....	94
5.4.1	Basic design of the neighborhood function	94
5.4.2	Generation of the transfer value	96
5.4.3	Monitoring of the constraints' satisfaction	99
5.5	Generation of the threshold sequence.....	101
5.6	Parallelization of threshold accepting.....	104
6	PARAMETERIZATION OF THRESHOLD ACCEPTING.....	107

6.1	Concept of successive parameterization in context with the present model	107
6.2	Effective combinations of thresholds and transfer values	108
6.2.1	Simple parameterization by visual analysis.....	108
6.2.2	Comprehensive analysis on the basis of detailed grid structures.....	112
6.2.3	Excursus on the impact of the transfer value generation on the parameterization	115
6.3	Effective combinations of restarts and steps.....	119
6.3.1	Appropriate coverage of the solution space.....	119
6.3.2	Particular aspects of parallel computing.....	121
6.4	Concluding remarks on the parameterization for different model cases.....	123
7	SUPERIORITY OF OPTIMAL ECONOMIC CAPITAL ALLOCATION – THE INFORMED CENTRAL PLANNER	125
7.1	Introduction to the benchmarking of allocation methods in case of an informed central planner	125
7.2	Benchmarking of allocation methods in case of an informed central planner	127
7.2.1	Allocation methods’ performances before the background of an arbitrary model bank.....	127
7.2.2	Precise benchmarking on the basis of particular model settings ..	132
7.2.2.1	Implementation of a level playing field.....	132
7.2.2.2	Impact of restrictions through minimum limits.....	135
7.2.2.3	Relevance of optimal allocation in case of less privately informed traders.....	138
7.2.2.4	Influence of higher degrees of diversification in the form of higher numbers of business units.....	141
7.3	Discussion of the superiority of optimal economic capital allocation	143
8	UNINFORMED CENTRAL PLANNER – INFORMATION ON THE BASIS OF BAYESIAN LEARNING	147
8.1	Introduction to the case of an uninformed central planner	147
8.2	Description of the Bayesian learning algorithm	148

- 8.3 Bayesian learning central planner in case of independently acting decision makers 153
 - 8.3.1 Benchmarking of allocation methods using perfect prior probabilities 153
 - 8.3.2 Benchmarking under adjusted prior probabilities for the anticipation of risk underestimation 160
- 8.4 Influence of herding decision makers on optimal economic capital allocation 168
 - 8.4.1 Herding and informational cascades in case of economic capital allocation..... 168
 - 8.4.2 Modeling of herding tendencies among the decision makers..... 170
 - 8.4.3 Benchmarking of allocation methods under herding decision makers..... 176
- 8.5 Conclusions on optimal allocation before the background of an uninformed central planner..... 187
- 9 CONCLUSIONS 191
 - 9.1 Summary of results 191
 - 9.2 Closing remarks on the model assumptions and suggested future research..... 194
- APPENDIX..... 195
- REFERENCES 207

FIGURES

Figure 2.1: Extract of an exemplary VAR limit system.....	30
Figure 2.2: Economic capital allocation and risk management process.....	35
Figure 2.3: Qualitative outline of the adjustment cost function.....	38
Figure 4.1: Structure of the simulation of the business units' profits and losses.....	77
Figure 4.2: Distribution of the probabilities of success p on the basis of a beta PDF with $\alpha = 1$, $\beta = 9$ and on the interval $[0.5, 1]$	79
Figure 4.3: Exemplary illustration of importance sampling (IS) in the form of scaling on the basis of a histogram (black with, dashed without IS).....	81
Figure 5.1: Extract from an exemplary solution space surface.....	86
Figure 5.2: Outline of the neighborhood function $N(\mathbf{v}^c)$	95
Figure 5.3: Exemplary sequence of transfer values \mathbf{tr} for $exp = 2$	97
Figure 5.4: Exemplary empirical distribution of deltas incl. threshold sequence $\boldsymbol{\tau}$	102
Figure 5.5: Applied structure of parallel computing.....	104
Figure 6.1: Choice of potential $tr_{init}-p_{\tau}$ combinations by a 2x2-grid.....	109
Figure 6.2: Visualization of the search behavior of $tr_{init}-p_{\tau}$ combinations on the basis of single restarts.....	110
Figure 6.3: Potential refinement of the search for appropriate $tr_{init}-p_{\tau}$ combinations.....	111
Figure 6.4: Investigation of 400 different $tr_{init}-p_{\tau}$ combinations each undergoing 60 restarts.....	112
Figure 6.5: The best out of 60 restarts under $tr_{init} = 300$ and $p_{\tau} = 0.75$ representing the current example's most promising parameterization (achieving $\mu_{bank} = 157.67$).....	113
Figure 6.6: Empirical distributions of μ_{bank} for 60 restarts each using the different $tr_{init}-p_{\tau}$ combinations 1 - 5 from figure 6.2 and figure 6.5.....	114
Figure 6.7: Investigation of μ_{bank} of 400 different $tr_{init}-p_{\tau}$ combinations each undergoing 60 restarts using a randomized (upper) and a fix transfer value (lower).....	116

Figure 6.8: Empirical distributions of the best solutions for μ_{bank} out of 60 restarts concerning the 400 different $tr_{\text{init}}-p_{\tau}$ combinations using a decreasing / randomized, randomized and fix transfer value according to figure 6.4 and the figure 6.7..... 117

Figure 6.9: Empirical distributions of the solutions μ_{bank} of 400 restarts using a decreasing / randomized, randomized and fix transfer value and the respective transfer value method's optimal $tr_{\text{init}}-p_{\tau}$ combination according to the figure 6.4 and the figure 6.7..... 118

Figure 6.10: Empirical distributions of the restarts' solutions μ_{bank} according to the parameterizations from table 6.1..... 120

Figure 7.1: Limit allocations according to the TA, expected return, uniform and random method using $ec = 1\text{k}$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 50$, $p_{\varnothing} = 0.55$ and $m = 20\text{k}$, arranged according to the business units' in-sample expected return..... 128

Figure 7.2: Histograms of the allocation methods' out-of-sample results concerning pl_{bank} using $ec = 1\text{k}$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 50$, $p_{\varnothing} = 0.55$ and $m = 20\text{k}$ 131

Figure 7.3: Limit allocations according to the TA, expected return, uniform and random method using $ec = 662$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 50$, $p_{\varnothing} = 0.55$ and $m = 20\text{k}$, arranged according to the business units' in-sample return expectations..... 133

Figure 7.4: Histograms of the allocation methods' out-of-sample results concerning pl_{bank} using $ec = 662$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 50$, $p_{\varnothing} = 0.55$ and $m = 20\text{k}$ 134

Figure 7.5: Limit allocations according to the TA, expected return, uniform and random, method using $ec = 550$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 50$, $p_{\varnothing} = 0.55$, $vl_{\text{min}} = 50$ and $m = 20\text{k}$, arranged according to the business units' in-sample expected returns..... 136

Figure 7.6: Histograms of the allocation methods' out-of-sample results concerning pl_{bank} using $ec = 550$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 50$, $p_{\varnothing} = 0.55$, $vl_{\text{min}} = 50$ and $m = 20\text{k}$ 137

Figure 7.7: Adjustment of the skill levels' distribution from $p_{\varnothing} = 0.55$ to $p_{\varnothing} = 0.51$ 138

Figure 7.8: Limit allocations according to the TA, expected return, uniform and random method using $ec = 901$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 50$,

- $p_\emptyset = 0.51$, $vl_{\min} = 50$ and $m = 20k$, arranged according to the business units' in-sample expected returns..... 139
- Figure 7.9: Histograms of the allocation methods' out-of-sample results concerning pl_{bank} using $ec = 901$, $c_{\text{bank}} = 150k$, $n_{\text{units}} = 50$, $p_\emptyset = 0.51$, $vl_{\min} = 50$ and $m = 20k$ 140
- Figure 7.10: Limit allocations according to the TA, expected return, uniform and random method using $ec = 417$, $c_{\text{bank}} = 150k$, $n_{\text{units}} = 200$, $p_\emptyset = 0.51$, $vl_{\min} = 12.5$ and $m = 20k$, arranged according to the business units' in-sample expected returns..... 141
- Figure 7.11: Histograms of the allocation methods' out-of-sample results concerning pl_{bank} using $ec = 417$, $c_{\text{bank}} = 150k$, $n_{\text{units}} = 200$, $p_\emptyset = 0.51$, $vl_{\min} = 12.5$ and $m = 20k$ 142
- Figure 8.1: Discretization of the model world's skill levels by trader types ... 149
- Figure 8.2: Exemplary p_j^ϵ -values of $n_{\text{updates}} = 20k$ successive Bayesian updates (zoom on the first 2.5k p_j^ϵ -values on the right) for business units actually exhibiting $p_1 = 0.544$ (petrol), $p_2 = 0.521$ (violet) and $p_3 = 0.5$ (pink)..... 151
- Figure 8.3: Illustration of the influence of formula (8.8) on the distribution of the trader types p_k 152
- Figure 8.4: Limit allocations using $ec \approx 400$, $c_{\text{bank}} = 150k$, $n_{\text{units}} = 200$, $p_\emptyset = 0.51$, $vl_{\min} = 12.5$ and $m = 20k$, arranged according to the business units' out-of-sample (actual) expected returns 154
- Figure 8.5: Out-of-sample results for μ_{bank} (upper) and the relative advantage of the TA method (lower) for the n_{updates} -values [1, 2k] using $ec \approx 400$, $c_{\text{bank}} = 150k$, $n_{\text{units}} = 200$, $p_\emptyset = 0.51$, $vl_{\min} = 12.5$ and $m = 20k$ 159
- Figure 8.6: Out-of-sample results for confidence level β for the n_{updates} -values [1, 2k] using $ec \approx 400$, $c_{\text{bank}} = 150k$, $n_{\text{units}} = 200$, $p_\emptyset = 0.51$, $vl_{\min} = 12.5$ and $m = 20k$ 160
- Figure 8.7: Illustration of the impact of formula (8.9) on the occurrences θ_k of the trader types p_k on the basis of the types' distribution 162
- Figure 8.8: Limit allocations using $ec \approx 400$, $c_{\text{bank}} = 150k$, $n_{\text{units}} = 200$, $p_\emptyset = 0.51$, $p_{k,\emptyset} = 0.506$, $vl_{\min} = 12.5$ and $m = 20k$, arranged according to the business units' out-of-sample (actual) return expectations..... 163
- Figure 8.9: Out-of-sample results for μ_{bank} (upper) and the relative advantage of the TA method (lower) for the n_{updates} -values [1, 2k] using

roughly $ec \approx 400$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 200$, $p_{\emptyset} = 0.51$, $p_{k,\emptyset} = 0.506$, $v_{l_{\text{min}}} = 12.5$ and $m = 20\text{k}$	166
Figure 8.10: Out-of-sample results for confidence level β for the n_{updates} -values [1, 2k] using $ec \approx 400$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 200$, $p_{\emptyset} = 0.51$, $p_{k,\emptyset} = 0.506$, $v_{l_{\text{min}}} = 12.5$ and $m = 20\text{k}$	167
Figure 8.11: Distribution of the market trends q on the basis of a beta PDF with $\alpha = 2$, $\beta = 2$ and on the interval $[0, 1]$	171
Figure 8.12: Histogram (upper) and CDF (lower) of actual trend occurrences on the basis of the GBM-returns using $m = 20\text{k}$ compared to the CDF of the prior probabilities ψ	172
Figure 8.13: Probability structure for the Bayesian learning concerning the market trend	174
Figure 8.14: Informational cascades on the basis of the development of q_j^e during the trading of the model bank	176
Figure 8.15: Limit allocations using $ec \approx 1\text{k}$, $c_{\text{bank}} \approx 150\text{k}$, $n_{\text{units}} = 200$, $p_{\emptyset} = 0.51$, $v_{l_{\text{min}}} = 12.8$ and $m = 20\text{k}$, arranged according to the business units' out-of-sample (actual) return expectations	178
Figure 8.16: Histograms concerning the shares of long positions for the herding tendencies of 25 % (black) and 0 % (dotted) for the exemplary case of $n_{\text{updates}} = 1\text{k}$	180
Figure 8.17: Histograms of the allocation methods' out-of-sample results concerning $p_{l_{\text{bank}}}$ for the herding tendencies of 25 % and 0 % (dotted) for the exemplary case of $n_{\text{updates}} = 1\text{k}$	181
Figure 8.18: Out-of-sample results for μ_{bank} (upper) and the relative advantage of the TA method (lower) for the n_{updates} -values [1, 2k] and 25 % herding tendency using $ec \approx 1\text{k}$, $c_{\text{bank}} \approx 150\text{k}$, $n_{\text{units}} = 200$, $p_{\emptyset} = 0.51$, $v_{l_{\text{min}}} = 12.8$ and $m = 20\text{k}$	183
Figure 8.19: Out-of-sample results for confidence level β for the n_{updates} -values [1, 2k] and 25 % herding tendency using $ec \approx 1000$, $c_{\text{bank}} \approx 150\text{k}$, $n_{\text{units}} = 200$, $p_{\emptyset} = 0.51$, $v_{l_{\text{min}}} = 12.8$ and $m = 20\text{k}$	184
Figure 8.20: Superiority of the TA method concerning μ_{bank} for different herding tendencies across the interval $[0, 1]$ compared to the expected return (blue), the uniform (red) and the random method (orange)	185

TABLES

Table 2.1:	Categorization for the different components of economic capital	26
Table 2.2:	Cost dimensions of ex post adjustments of total risk through a central treasury department	37
Table 6.1:	Different potential parameterizations for nrestarts and n_{steps} using $n_{comp} = 1,200k$, $n_{rounds} = 10$, $tr_{init} = 300$ and $p_{\tau} = 0.75$	120
Table 6.2:	Probability p_{λ} of the different parameterization's single restarts.....	122
Table 6.3:	Probability π_{λ} of the respective parameterization	122
Table 6.4:	Required number of restarts nrestarts and computational resources ncomp of the respective parameterization for $\pi_{\lambda} = 0.99$	123
Table 7.1:	In-sample results using $ec = 1k$, $c_{bank} = 150k$, $n_{units} = 50$, $p_{\varnothing} = 0.55$ and $m = 20k$	129
Table 7.2:	Out-of-sample results using $ec = 1k$, $c_{bank} = 150k$, $n_{units} = 50$, $p_{\varnothing} = 0.55$ and $m = 20k$	131
Table 7.3:	In-sample results using $ec = 662$, $c_{bank} = 150k$, $n_{units} = 50$, $p_{\varnothing} = 0.55$ and $m = 20k$	133
Table 7.4:	Out-of-sample results using $ec = 662$, $c_{bank} = 150k$, $n_{units} = 50$, $p_{\varnothing} = 0.55$ and $m = 20k$	135
Table 7.5:	In-sample results using $ec = 550$, $c_{bank} = 150k$, $n_{units} = 50$, $p_{\varnothing} = 0.55$, $v_{lmin} = 50$ and $m = 20k$	136
Table 7.6:	Out-of-sample results using $ec = 550$, $c_{bank} = 150k$, $n_{units} = 50$, $p_{\varnothing} = 0.55$, $v_{lmin} = 50$ and $m = 20k$	137
Table 7.7:	In-sample results using $ec = 901$, $c_{bank} = 150k$, $n_{units} = 50$, $p_{\varnothing} = 0.51$, $v_{lmin} = 50$ and $m = 20k$	139
Table 7.8:	Out-of-sample results using $ec = 901$, $c_{bank} = 150k$, $n_{units} = 50$, $p_{\varnothing} = 0.51$, $v_{lmin} = 50$ and $m = 20k$	140
Table 7.9:	In-sample results using $ec = 417$, $c_{bank} = 150k$, $n_{units} = 200$, $p_{\varnothing} = 0.51$, $v_{lmin} = 12.5$ and $m = 20k$	142
Table 7.10:	Out-of-sample results using $ec = 417$, $c_{bank} = 150k$, $n_{units} = 200$, $p_{\varnothing} = 0.51$, $v_{lmin} = 12.5$ and $m = 20k$	143

Table 8.1:	In-sample results for $n_{\text{updates}} = 250$ (upper), = 1k (middle) and = 20k (lower) using $ec \approx 400$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 200$, $p_{\emptyset} = 0.51$, $vl_{\text{min}} = 12.5$ and $m = 20\text{k}$	156
Table 8.2:	Out-of-sample results for $n_{\text{updates}} = 250$ (upper), = 1k (middle) and = 20k (lower) using $ec \approx 400$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 200$, $p_{\emptyset} = 0.51$, $vl_{\text{min}} = 12.5$ and $m = 20\text{k}$	157
Table 8.3:	In-sample results for $n_{\text{updates}} = 250$ (upper), = 1k (middle) and = 20k (lower) using $ec \approx 400$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 200$, $p_{\emptyset} = 0.51$, $p_{k,\emptyset} = 0.506$, $vl_{\text{min}} = 12.5$ and $m = 20\text{k}$	164
Table 8.4:	Out-of-sample results for $n_{\text{updates}} = 250$ (upper), = 1k (middle) and = 20k (lower) using $ec \approx 400$, $c_{\text{bank}} = 150\text{k}$, $n_{\text{units}} = 200$, $p_{\emptyset} = 0.51$, $p_{k,\emptyset} = 0.506$, $vl_{\text{min}} = 12.5$ and $m = 20\text{k}$	165
Table 8.5:	In-sample results for $n_{\text{updates}} = 250$ (upper), = 1k (middle) and = 20k (lower) using $ec \approx 1000$, $c_{\text{bank}} \approx 150\text{k}$, $n_{\text{units}} = 200$, $p_{\emptyset} = 0.51$, $vl_{\text{min}} = 12.8$ and $m = 20\text{k}$	179
Table 8.6:	Out-of-sample results for $n_{\text{updates}} = 250$ (upper), = 1k (middle) and = 20k (lower) using $ec \approx 1000$, $c_{\text{bank}} \approx 150\text{k}$, $n_{\text{units}} = 200$, $p_{\emptyset} = 0.51$, $vl_{\text{min}} = 12.8$ and $m = 20\text{k}$	182

ALGORITHMS

Algorithm 5.1: Threshold accepting.....	88
Algorithm 5.2: Computation of random and feasible starting solution \mathbf{v}^1	90
Algorithm 5.3: Computation of a random starting solution inducing maximum use of the available investment capital c_{bank} and economic capital ec	92
Algorithm 5.4: Binary search algorithm for adjusting the scaling factor φ	93
Algorithm 5.5: Implementation of the neighborhood function $N(\mathbf{v}^c)$	96
Algorithm 5.6: Final determination of the transfer value tr_i	99
Algorithm 5.7: Monitoring of the budget constraint and the VAR limit of the bank	100
Algorithm 5.8: Generation of the threshold sequence τ	101
Algorithm 5.9: Communication between the master and the servants.....	105

1 INTRODUCTION

1.1 Problem and research question

The financial crisis revealed, among other things, in particular one shortcoming of the financial system: Banks do not provide enough liable equity in order to cover unexpected losses and guarantee their going concern with sufficient certainty. As a consequence, the Basel Committee of Banking Supervision introduced a new accord, known under the term Basel III.¹ The accord's main concern refers to the increase of the liable equity of banks and the improvement of the equity's quality. The guidelines demand the capital adequacy ratio (CAR) of the banks to increase especially for systemically important banks. The CAR measures the ratio of liable equity to risk weighted assets (RWA). The increase of the liable equity causes a considerable cost pressure on the financial institutions, the quality improvements not to mention. In order to keep their profit margins, the institutions will be increasingly forced to strictly manage their institution-wide businesses according to risk-return aspects in a portfolio theoretical sense. This, however, demands for a comprehensive ex-ante-equity management.

The present approach of research describes such a system of corporate management on the basis of a model. The model exclusively takes into account the available equity of a bank and completely dispenses with funding issues. In order to be able to extensively examine the portfolio theoretical aspects of this system of corporate management, the model chooses the economic instead of the regulatory perspective. As a consequence, the model focusses on the economic equivalent of liable equity in the form of economic capital.² The economic perspective assesses risk by downside-risk measures instead of using the RWA-methodology.³

The present corporate management system allocates the risk-bearing potential of the economic capital to the business units by value at risk (VAR) limits. This enables the units to take risks and operate business according to their respective limit's extent. The transmission of the business strategy from the central management to the decentralized decision makers⁴ therefore manifests by the strate-

¹ See Basel Committee of Banking Supervision (2011) for the Basel III accord and Deutsche Bundesbank (2011) or Auer and Pfoestl (2011) for overviews concerning the Basel III guidelines.

² See chapter 2.1 for details on the definition of economic capital.

³ See chapter 2.2 for an introduction of the downside risk measures VAR and expected shortfall (ES).

⁴ The following uses the expressions "decision maker" and "business unit" synonymously.

gic setting of the limits. The VAR limits finally represent decision rights determining the range for the autonomous decision making by the business units.

Nevertheless, this kind of corporate management bears conflicting objectives.⁵ For the consideration of portfolio theoretical aspects, the central management requires precise information concerning the correlations between the returns of the business units' business opportunities. The use of delegation advantages, however, depends on the autonomous decision making of the business units which are free to choose long or short positions. Unfortunately, this autonomous decision making causes unstable correlations between the units' businesses which significantly complicates an optimal corporate management in the portfolio theoretical sense. Further difficulties represent the portfolio theoretical consideration of the decision makers' individual prospects of success and their interactions⁶ potentially influencing their decision making.

The differentiated modeling of such a corporate management system is technically demanding. The consideration of the decision makers' individual prospects of success causes the business units' returns to follow non-elliptical distributions. This fact excludes the use of common analytical optimization to achieve the most advantageous limit allocations. The non-elliptical distributions turn the underlying optimization problem into a global problem requiring heuristic optimization for proper solving. The present model of optimal allocation of economic capital uses the threshold accepting (TA) algorithm for heuristic optimization. However, compared to the relevant literature, the present implementation of the TA-algorithm requires certain modifications.⁷

The central research question of the present approach concerns whether the optimal allocation of economic capital according to portfolio theoretical aspects represents the superior corporate management approach. The research approach addresses this question under the model assumption of strictly rational behaving players. The central research question subdivides into several partial objectives.

The first step consists in developing a consistent model reflecting the situation of corporate management by economic capital allocation sufficiently detailed. From the modeling of the economical processes also different technical challenges arise.

⁵ See Froot and Stein (1998) identifying these conflicting objectives in their final conclusions and emphasizing the need for further research on this conflict's proper consideration by integral bank management approaches in the portfolio theoretical sense.

⁶ See Burghof and Sinha (2005) modeling this interaction in the form of herd behavior and identifying correlations between decisions as the main risk drivers. Their analyses, however, dispense with the optimization of the VAR limit system in a portfolio theoretical sense.

⁷ See Gilli et al. (2006) applying and developing TA in context with portfolio optimization under downside risk constraints. Besides the high relevance of their approach for the present implementation of TA, there are significant differences compared to the present optimization of VAR limit systems.

Technical challenges arise from the fact that the present approach addresses the optimization of VAR limits instead of common portfolio optimization under a VAR constraint.⁸ As a consequence, the extents of the decision variables in the form of the limits do not depend on a known budget constraint but on unknown diversification effects. This requires modifications of the implementation of TA compared to the case of common portfolio optimization under a VAR constraint.

The finished model then allows addressing the central concern of the present research on the basis of different model analyses. These analyses successively adjust the setting for the optimal allocation of economic capital by imposing more restrictive and realistic conditions.

A central adjustment refers to the replacement of an informed central management by an uninformed one. In contrast to the informed management, the uninformed one has to acquire the relevant information concerning the business units by rational learning. The model case enables analyzing whether an optimal allocation of economic capital is still relevant under the more realistic scenario of increased uncertainty arising from less precise information.

A second central adjustment compared to the initial model case concerns the independent and autonomous decision making of the business units. Therefore, the independent decision making undergoes restrictions by the introduction of herd behavior. Herd behavior manifests in the present model by decision makers imitating investment decisions observed from their colleagues as soon as following their individual information appears less promising from a rational perspective. This influences the correlations between the investment decisions and induces additional uncertainty. The model case aims at analyzing whether corporate management on the basis of VAR limit systems fundamentally accomplishes anticipating herd behavior of the decision makers.

The present modeling and analysis of optimal corporate management by VAR limit systems generally aims at disclosing the requirements of such a corporate management approach.

1.2 Organization of the research

The research subdivides into nine chapters. After this introduction two further preparatory chapters describe the basic issues of economic capital allocation and the implications of the literature of related fields of research. Subsequently, three chapters address the modeling and implementation of the relevant econom-

⁸ See Burghof and Müller (2012) for insights on the differences between common portfolio optimization under a VAR constraint and the optimization of VAR limit systems in context with the use of TA.