PUBLICATIONS OF THE NEWTON INSTITUTE

Worldwide Asset and Liability Modeling

Publications of the Newton Institute

Edited by H.K. Moffatt

Director, Isaac Newton Institute for Mathematical Sciences

The Isaac Newton Institute of Mathematical Sciences of the University of Cambridge exists to stimulate research in all branches of the mathematical sciences, including pure mathematics, statistics, applied mathematics, theoretical physics, theoretical computer science, mathematical biology and economics. The four six-month long research programmes it runs each year bring together leading mathematical scientists from all over the world to exchange ideas through seminars, teaching and informal interaction.

WORLDWIDE ASSET AND LIABILITY MODELING

edited by

William T. Ziemba

University of British Columbia

and

John M. Mulvey

Princeton University

CAMBRIDGE UNIVERSITY PRESS

PUBLISHED BY THE PRESS SYNDICATE OF THE UNIVERSITY OF CAMBRIDGE
The Pitt Building, Trumpington Street, Cambridge CB2 1RP, United Kingdom

CAMBRIDGE UNIVERSITY PRESS
The Edinburgh Building, Cambridge CB2 2RU, United Kingdom
40 West 20th Street, New York, NY 10011-4211, USA
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

First published 1998

Reprinted with corrections 1999

Typeset in 12pt Computer Modern

A catalogue record for this book is available from the British Library

ISBN 0 521 57187 1 hardback

Transferred to digital printing 2004

CONTENTS

Acknowledgements viii

List of contributors ix

Preface
William T. Ziemba xiii

PART I. INTRODUCTION

1. Asset and liability management systems for long-term investors: discussion of the issues
John M. Mulvey and William T. Ziemba 3

PART II. STATIC PORTFOLIO ANALYSIS FOR ASSET ALLOCATION

2. The importance of the asset allocation decision
Chris R. Hensel, D. Don Ezra and John H. Ilkiw 41

3. The effect of errors in means, variances, and covariances on optimal portfolio choice
Vijay K. Chopra and William T. Ziemba 53

4. Making superior asset allocation decisions: a practitioner's guide
Chris R. Hensel and Andrew L. Turner 62

PART III. PERFORMANCE MEASUREMENT MODELS

5. Attribution of performance and holdings
Richard C. Grinold and Kelly A. Easton 87

6. National versus global influences on equity returns
Stan Beckers, Gregory Connor and Ross Curds 114

7. A global stock and bond model
Lucie Chaumeton, Gregory Connor and Ross Curds 129

PART IV. DYNAMIC PORTFOLIO MODELS FOR ASSET ALLOCATION

8. On timing the market: the empirical probability assessment approach with an inflation adapter
Robert R. Grauer and Nils Hakansson 149

9. Multiperiod asset allocation with derivative assets
David R. Cariño and Andrew L. Turner 182

10. The use of Treasury bill futures in strategic asset allocation programs
Michael J. Brennan and Edwardo S. Schwartz 205

PART V. SCENARIO GENERATION PROCEDURES

11. Barycentric approximation of stochastic interest rate processes
Karl Frauendorfer and Michael Schürle 231

12. Postoptimality for scenario based financial planning models with an application to bond portfolio management
Jitka Dupačovà, Marida Bertocchi and Vittorio Moriggia 263

13. The Towers Perrin global capital market scenario generation system
John M. Mulvey and A. Eric Thorlacius 286

PART VI. CURRENCY HEDGING AND MODELING TECHNIQUES

14. An algorithm for international portfolio selection and optimal currency hedging
Markus Rudolf and Heinz Zimmerman 315

15. Optimal insurance asset allocation in a multi-currency environment
John C. Sweeney, Stephen M. Sonlin, Salvatore Correnti and Amy P. Williams 341

PART VII. DYNAMIC PORTFOLIO ANALYSIS WITH ASSETS AND LIABILITIES

16. Optimal investment strategies for university endowment funds
Robert C. Merton 371

17. Optimal consumption-investment decisions allowing for bankruptcy: a survey
Suresh Sethi 397

18. Solving stochastic programming models for asset/liability management using iterative disaggregation
Pieter Klaassen 427

19. The CALM stochastic programming model for dynamic asset-liability management
Giorgio Consigli and Michael A.H. Dempster 464

20. A dynamic model for asset liability management for defined benefit pension funds
Cees Dert 501

21. Asset and liability management under uncertainty for fixed income securities
Stavros A. Zenios 537

PART VIII. CASE STUDIES OF IMPLEMENTED ASSET-LIABILITY MANAGEMENT MODELS

22. Modelling and management of assets and liabilities of pension plans in the Netherlands
Guus C. E. Boender, Paul van Aalst and Fred Heemskerk 561

23. Integrated asset-liability management: an implementation case study
Martin Holmer 581

PART IX. TOTAL INTEGRATIVE RISK MANAGEMENT MODELS

24. The Russell–Yasuda Kasai model: an asset/liability model for a Japanese insurance company using multistage stochastic programming
David R. Cariño, Terry Kent, David H. Myers, Celine Stacy, Michael Sylvanus, Andrew Turner, Kanji Watanabe and William T. Ziemba ...609

25. The Home Account Advisor™: asset and liability management for individual investors
Adam J. Berger and John M. Mulvey 634

ACKNOWLEDGEMENTS

We thank the following publishers and authors for allowing us to reproduce the articles listed below:

'The importance of the asset allocation decision,' Chris R. Hensel, D. Don Ezra and John H. Ilkiw. Reprinted from *Financial Analysts Journal*, 1991 (July-August): 65–72.

'The effect of errors in means, variances, and covariances on optimal portfolio choice,' Vijay K. Chopra and William T. Ziemba. Reprinted from *Journal of Portfolio Management*, 1993 (Winter): 6–11.

'The comparative performance of global vs international models of equity market risk,' Stan Beckers, Gregory Connor and Ross Curds. Reprinted from *Financial Analysts Journal* **52** (2) 1996: 31–39.

'A global stock and bond model,' Lucie Chaumeton, Gregory Connor and Ross Curds. Reprint from *Financial Analysts Journal* **52** (6) 1996: 65–74.

'Optimal investment strategies for university endowment funds,' Robert C. Merton. Reprinted from *Studies of Supply and Demand in Higher Education*, Charles T. Clotfelter and Michael Rothschild, eds., University of Chicago Press, 1993: 211–236.

'The CALM stochastic programming model for dynamic asset-liability management,' Georgio Consigli and Michael A.H. Dempster. Reprinted from *Annals of Operations Research*, 1998 (in press).

'Asset and liability management under uncertainty for fixed income securities,' Stavros A. Zenios. Reprinted from *Annals of Operations Research* **59** 1995: 77–97.

'The Russell–Yasuda Kasai model: an asset/liability model for a Japanese insurance company using multistage stochastic programming,' David R. Cariño, Terry Kent, David H. Myers, Celine Stacy, Michael Sylvanus, Andrew Turner, Kanji Watanabe and William T. Ziemba. Reprinted from *Interfaces* **24** (1) 1994: 24–49.

CONTRIBUTORS

Stan Beckers, BARRA International Ltd, 1 Whittington Ave, London EC3V 1LE, England.

Adam J. Berger, Lattice Financial LLC, 55 Princeton–Hightstown Road, Princeton Junction, NJ 08550, USA

Marida Bertocchi, University of Bergamo, Department of Mathematics, Piazza Rosate 2, I-24129 Bergamo, Italy.

C.G.E. Boender, ORTEC Consultants bv, Groningenweg 6–33, 2803 PV Gouda, The Netherlands; *and* Free University Amsterdam, De Boelelaan 1107, 1081 HV Amsterdam, The Netherlands; *and* Erasmus University Rotterdam, P.O. Box 1738, 3000 DR Rotterdam, The Netherlands.

Michael J. Brennan, John E. Anderson Graduate School of Management, UCLA, 110 Westwood Plaza, Box 951481, Los Angeles, CA 90095–1481, USA; *and* London Business School, Sussex Place, Regent's Park, London NW 1 4SA, UK.

David R. Cariño, Frank Russell Company Pty Ltd, GPO Box 5291, Sydney NSW 2001, Australia.

Lucie Chaumeton, BARRA International Ltd, 1 Whittington Ave, London EC3V 1LE, England.

Vijay Kumar Chopra, Bankers Trust Company, 130 Liberty Street, MS 2355 New York, NY 10006, USA.

Gregory Connor, BARRA International Ltd, 1 Whittington Ave, London EC3V 1LE, England.

Giorgio Consigli, Finance Directorate, Head Office, UniCredito Italiano, Via San Protaso 3 20121 Milano, Italy.

Sal Correnti, Falcon Asset Management Inc., Harborplace Tower, 18th Floor, 111 South Charles Street, Baltimore, MD 21202, USA.

Ross Curds, BARRA International Ltd, 1 Whittington Ave, London EC3V 1LE, England.

Michael A.H. Dempster, Judge Institute of Management Studies, University of Cambridge, Cambridge CB2 1AG, England.

Cees Dert, Vrije Universiteit Amsterdam, Faculteit der Economische Wetenschappen en Econometrie, Vakgroep BFS, De Boelelaan 1105, NL 1081 HV Amsterdam, The Netherlands; *and* ABN AMRO Asset Management, PAC AA 3260, PO Box 283, NL 1000 AE Amsterdam, The Netherlands.

Jitka Dupačovà, Charles University Prague, Department of Probability and Mathematical Statistics, Sokolovská 83, CZ-186 00 Prague, Czech Republic.

Kelly A. Easton, BZW Barclays Global Investors, 45 Fremont St, San Francisco, CA 94105, USA.

D. Don Ezra, Frank Russell Company, 909 A Street Tacoma, Washington 98402, USA.

Karl Frauendorfer, Institute of Operations Research, University of St. Gallen, Holzstrasse 15, CH-9010 St. Gallen, Switzerland.

Robert R. Grauer, Department of Economics and Faculty of Business, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6.

Richard C. Grinold, BZW Barclays Global Investors, 45 Fremont St, San Francisco, CA 94105, USA.

Nils Hakansson, Haas School of Business, University of California, Berkeley, 350 Barrows Hall, Berkeley, CA 94720, USA.

Fred Heemskerk, ORTEC Consultants bv Groningenweg 6-33, 2803 PV Gouda, The Netherlands.

Chris R. Hensel, Frank Russell Company, 909 A Street Tacoma, Washington 98402, USA.

Martin Holmer, Policy Simulation Group, 1314 Kearney Street, NE Washington, DC 20017, USA

John H. Ilkiw, Frank Russell Company, 909 A Street Tacoma, Washington 98402, USA.

Terry Kent, US Olympic Society, Lake Placid, NY, USA.

Pieter Klaassen, Vrije Universiteit, Financial Sector Management, Department of Economics and Econometrics, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands; *and* Rabobank International, Postbus 17100, 3500 HG Utrecht, The Netherlands.

Robert C. Merton, Harvard Business School, Harvard University, Morgan 397, Soldiers Field, Boston, MA 02163, USA.

Vittorio Moriggia, University of Bergamo, Department of Mathematics, Piazza Rosate 2, I-24129 Bergamo, Italy.

John M. Mulvey, School of Engineering and Applied Science, Princeton University, Princeton, NJ 08544, USA

David H. Myers, School of Business, University of Washington, Seattle, WA 98185, USA.

Markus Rudolf, University of St. Gallen, Merkurstr. 1, CH-9000 St. Gallen, Switzerland.

Michael Schürle, Institute of Operations Research, University of St. Gallen, Holzstrasse 15, CH-9010 St. Gallen, Switzerland.

Edwardo S. Schwartz, John E. Anderson Graduate School of Management, UCLA, 110 Westwood Plaza, Box 951481, Los Angeles, CA 90095–1481, USA.

Suresh Sethi, Faculty of Management, Joseph L. Rotman Centre for Management, University of Toronto, 105 St George St., Toronto, Canada M5S 3E6.

Steve Sonlin, Falcon Asset Management Inc., Harborplace Tower, 18th Floor, 111 South Charles Street, Baltimore, MD 21202, USA.

Celine Stacy, Frank Russell Company, 909 A Street Tacoma, Washington 98402, USA.

John C. Sweeney, Falcon Asset Management Inc., Harborplace Tower, 18th Floor, 111 South Charles Street, Baltimore, MD 21202, USA.

Michael Sylvanus, Frank Russell Company, 909 A Street Tacoma, Washington 98402, USA.

A. Eric Thorlacius, Falcon Asset Management Inc., Harborplace Tower, 18th Floor, 111 South Charles Street, Baltimore, MD 21202, USA.

Andrew L. Turner, Frank Russell Company, 909 A Street Tacoma, Washington 98402, USA.

Paul van Aalst, Erasmus University Rotterdam, P.O. Box 1738, 3000 DR Rotterdam, The Netherlands 4; *and* KPMG Brans and Co.

Kanji Watanabe, The Yasuda Fire and Marine Insurance Co., Ltd. Shinjuku-ku, Tokyo 160, Japan.

Amy P. Williams, Falcon Asset Management Inc., Harborplace Tower, 18th Floor, 111 South Charles Street, Baltimore, MD 21202, USA.

Stavros A. Zenios, University of Cyprus; *and* HERMES Laboratory for Financial Modeling and Simulation, Decision Sciences Department, The Wharton School, University of Pennsylvania, Philadelphia PA 19104, USA.

William T. Ziemba, Faculty of Commerce and Business Administration, The University of British Columbia, Vancouver, British Columbia V6T lY8, Canada.

Heinz Zimmermann, Swiss Institute of Banking, University of St. Gallen, Merkurstr. 1, CH-9000 St. Gallen, Switzerland.

Preface

Few problems are as important and complex to institutions and individuals as the management of their assets in such a way that their liabilities can be covered and their goals achieved. The assets must be invested over time to achieve favorable returns subject to various uncertainties, policy and legal constraints, taxes and other requirements, and liability commitments. Most investors, be they individuals or institutions, do not diversify properly across markets or across time, particularly in relation to their liability commitments. There are many motivations for studying asset liability management, including:

(a) the results may be useful to set guidelines for institutions and individual investors concerning their asset allocation mixes; the models integrate various decisions over time with the constraints, preferences and uncertainties inherent in the investment problem; and

(b) the models consider temporal dependence of asset returns and liability commitments, path dependent preferences, short and long term tradeoffs and provide for realistic measurement of risks and their tradeoff with investment returns considering the effects of taxes, transaction costs and other problem features.

To study this area, I organized a week-long set of research seminars under the general theme 'Worldwide asset and liability modeling,' on May 15–20, 1995 at the Isaac Newton Institute for Mathematical Science on the campus of the University of Cambridge. This research program was followed by an institutional investor workshop on Saturday May 20th. This week's activities formed part of the six month Financial Mathematics Seminar held at the Newton Institute from January to June 1995. I organized this part of the program under the general direction of the financial mathematics seminar organizers Mark Davis, Stewart Hodges, Ioannis Karatzas and Chris Rogers. This volume consists of twenty-five papers arising from this program. Most of the papers appearing here were presented in Cambridge with a few added to round out the volume.

The research papers in this volume utilize several approaches and integrate a number of techniques such as single period mean-variance, multi-period models using stochastic programming with and without specific decision rules, dynamic stochastic control, stochastic dynamic programming and simulation. These papers discuss a variety of models that have been implemented, are close to being implemented, or represent new innovative approaches that may lead to future novel applications.

The volume also discusses issues concerned with the future of asset-liability management modeling. This includes models for individuals and various financial institutions such as banks and insurance companies. This will lead to custom financial engineering products. These models hold much promise for the future to provide users with organized, diversified systems to help manage their financial affairs in an increasingly complex financial world. The models force diversification

and attention to extreme events and hence help minimize the possibility of financial disasters while at the same time providing good advice in ordinary circumstances balancing the various complex elements of the investor's situation.

The seminar in Cambridge took place in the efficient and most pleasant facilities of the Isaac Newton Institute on the campus of the University of Cambridge. The staff of the Institute, particularly Anne Cartwright, Florence Leroy, the Associate Director John Wright and Director Michael Atiyah were most helpful before and during our pleasant stay in Cambridge. Financial mathematics seminar chairman Chris Rogers was most supportive and helpful throughout this activity. My work in the practical use of asset and liability allocation models has been supported, encouraged and improved by my consulting association since 1989 with the Frank Russell company. Special thanks go to my Russell colleagues Chris Hensel and Andy Turner for their encouragement and our joint work. The Natural Sciences and Engineering Research Council of Canada has supported my research in stochastic programming including financial theory and asset-liability applications at the University of British Columbia since 1969. This support was very helpful with this project as well.

I was pleased to have John Mulvey join me as a co-editor of this volume. Besides co-authoring the introduction with me, John adds his special insights gained from years of outstanding research and consulting to improve the papers in this volume as well as contributing several outstanding co-authored papers based on his own pioneering work. Our editor David Tranah has been most helpful and patient in the preparation of this volume. Finally special thanks go to my wife Sandra Schwartz for much encouragement and help on the seminar in Cambridge and in the preparation of this volume.

William T. Ziemba
Vancouver