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Swaps and other derivatives

Second Edition

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Preface

EXTRACT FROM THE PREFACE TO THE FIRST EDITION

This book is designed for financial professionals to understand how the vast bulk of OTC derivatives are used, structured, priced and hedged, and ultimately how to use such derivatives themselves. A wide range of books already exist that describe in conceptual terms how and why such derivatives are used, and it is not the ambition of this book to supplant them. There are also a number of books which describe the pricing and hedging of derivatives, especially exotic ones, primarily in mathematical terms. Whilst exotics are an important and growing segment of the market, by far the majority of derivatives are still very much first generation, and as such relatively straightforward.

For example, interest rate swaps constitute over half of the $100 trillion OTC derivative market, and yet there have been few books published in the last decade that describe how they are created and valued in practical detail. So how do many of the professionals gain their knowledge? One popular way is "learning on the job", reinforced by the odd training course. But swap structures can be quite complex, requiring more than just superficial knowledge, and probably every professional uses a computer-based system, certainly for the booking and regular valuation of trades, and most likely for their initial pricing and risk management. These systems are complex, having to deal with real-world situations, and their practical inner details bear little resemblance to the idealised world of most books. So often, practitioners tend to treat the systems as black boxes, relying on some initial and frequently inadequate range of tests, and hoping their intuition will guide them. The greatest sources of comfort are often the existing customer list of the system (they can't all be wrong!) and, if the system is replacing an old one, comparative valuations.

The objective of this book is to describe how the pricing, valuation and risk management of generic OTC derivatives may be performed, in sufficient detail and with various alternatives, so that the approaches may be applied in practice. It is based upon some 15 years of varying experience as a financial engineer for ANZ Merchant Bank in London, as a trainer and consultant to banks worldwide, and as Director of Financial Engineering at Lombard Risk Systems responsible for all the mathematics in the various pricing and risk management systems.

The audience for the book is, first, traders, sales people and front-line risk managers. But increasingly such knowledge needs to be more widely spread within financial institutions, such as internal audit, risk control, and IT. Then there are the counterparties such as organisations using derivatives for risk management, who have frequently identified the need for transparent pricing. This need has been exacerbated in recent years as many developed countries now require that these organisations demonstrate the effectiveness of risk management, and also perform regular (usually annual) mark-to-market. Similarly, organisations using complex funding structures want to understand how the structures are created and priced. Turning to the other side, many fund managers and in particular hedge funds are also using derivatives to manage their risk profile, and then to report using one of the Value-at-Risk techniques. This has been particularly true since the collapse of Long Term Capital Management, despite the fact that most implementations of VaR would not have recognised the risk. Other potential readers are the auditors, consultants, and regulators of the banks and their client organisations.

PREFACE TO THE SECOND EDITION

Many of the above statements are still true. The swap market has continued to grow six-fold over the intervening years, to a staggering $328 trillion. Yet, there has been little published to provide guidance and assistance to the professionals in the market. Why was it thought useful to write a second edition? There were two main reasons. First, many readers had suggested changes and developments, which I thought appropriate to include. Second, the exponential growth in credit default swaps and structured securities identified areas which were little discussed in the first edition. This edition attempts to redress that omission.

Institutions offer derivatives with a wide range of maturities, ranging from a few hours (used to provide risk management over the announcement of an economic figure) to perpetuals (i.e. no upfront maturity defined). There is however a golden rule when pricing derivatives, namely always price them off the market that will be used to hedge them. This leads to the first separation in the interest rate swap market between:

Chapter 2: The short end of the curve, which uses cash, futures and occasionally FRAs to hedge swaps. This chapter first discusses the derivation of discount factors from cashrates, and concentrates on the range of alternative approaches that may be used. It then looks at the derivation of forward interest rates, and how FRAs may be priced using cash and futures. The convexity effect is highlighted for future discussion. Finally an approach is introduced that does not require discounting, but permits the introduction of a funding cost.

Chapter 3: The medium to long end of the curve. The highly liquid interbank market typically trades plain swaps (usually known as "generic" or "vanilla"), very often between market makers and intermediaries. These are hedged in other financial markets, typically futures for the shorter exposures and bonds for the longer ones. This chapter concentrates initially on the relationship between the bond and swap markets, and how generic swap prices may be implied. It concludes by developing various techniques for the estimation of discount factors from a generic swap curve.

Chapter 4: The end-user market provides customers with tailored (i.e. non-generic) swaps designed to meet their specific requirements. Such swaps are not traded as such, but created as one-off structures. This chapter describes a range of simple non-generic swaps, and discusses various techniques for pricing them, including one that requires no discounting. Finally two approaches to the ongoing valuation of an existing (seasoned) swap are demonstrated.

Chapter 5: Swaps are often used to restructure new or existing securities. This chapter describes some initial structures, par asset packaging and par maturity asset packaging, that are commonly used.

Chapter 6: Credit derivatives effectively evolved from the asset packaging or securitisation markets. The chapter first discusses total return swaps as being the earliest form of credit derivative, but then moves rapidly on to its successor, single-name credit default swaps. The chapter is in three parts. First, a broad description of the mechanics of the market, especially following the Big and Small Bangs in 2009. Second, an analysis of the relationship between asset packaging and the hedging of CDSs, leading to a discussion around the credit basis. Third, a derivation of implied forward default probabilities from CDS prices using a couple of slightly different approaches. This in turn allows the pricing of non-generic CDSs such as forward starts, amortising and floating rate.

Chapter 7: This discusses a range of more complex swaps known generally as mismatch swaps. This includes structures such as yield curve (also known as CMSs), in arrears, average rate, and compound. The chapter and its appendix re-introduce the concept of convexity-adjusted pricing more formally.

Chapter 8: This introduces a range of what are often called cross-market swaps. These involve the normal interbank floating rate (or indeed a fixed rate) on one side, and another reference rate drawn from another market on the other side, such as an overnight rate, or a base rate, or a mortgage rate, or an inflation rate, or an equity return, and so on. The main purpose of these swaps is to permit people with exposures in the other market to gain access to the range of risk management instruments that exists in the interbank market.

Chapter 9: The earliest swap structures were cross-currency swaps, although this market has been long overtaken by interest rate swaps. Nevertheless they possess some unique characteristics and structures. This chapter starts with the fundamental CCS building block, the cross-currency basis swap, and explores its characteristics, uses, pricing and hedging. This employs a novel approach: worst case simulation. The role of CCBSs in the derivation of cross-currency discount factors is also explored. The main other types of swaps are then discussed: fixed–floating, floating–floating, diff, and quanto–diff. Fixed–fixed swaps occupy a special place because they are a general case of long-term FX forward contracts, so the pricing and hedging of these is considered in some detail. Finally swap valuation is revisited because, in the CCS market, such swaps are frequently valued annually and the principals reset to the current exchange rate.

Chapter 10: There is an active market in many currencies in medium to long-term options on forward interest rates, usually known as the cap and floor market. Such structures are intimately linked to swaps for two reasons: first, because combinations of options can create swaps and, second, swaps are generally used to hedge them. In many banks, they are actually traded and risk-managed together. This chapter reviews a range of different option structures and touches albeit briefly on option pricing. Volatility plays a crucial role and various techniques for estimation, including transformation from par to forward as well as volatility smiles and volatility spaces, are described in detail. These options are also frequently embedded in many swap structures, and the breakdown and pricing of a range of structures is discussed. There is also an active market in options on forward swaps (aka swaptions or swoptions) which, not unnaturally, is closely related to the swap market. The pricing and embedding of swaptions is described. The chapter concludes with two sections on FX options. These options are mainly traded OTC, although there is some activity on a few exchanges such as Philadelphia. The first section concentrates on the pricing of these options, and how it may be varied depending on the method of quoting the underlying currencies. The second section shows how traders would dynamically create a delta-neutral hedge for such an option, together with the hedging errors through time.

Chapter 11: This chapter concentrates on more complex swaps arising from the need to swap structured securities. It starts by discussing the swapping of range accruals. It goes on to price structures such as callable bonds, Bermudan swaptions and path-dependent products such as target accrual redemption notes and snowballs using both numerical trees and Libor-based simulation.

Chapter 12: In the early days of the swap market, swap portfolios were risk-managed either using asset–liability methods such as gapping or the more advanced institutions used bond techniques such as duration. By the late 1980s a number of well-publicised losses had forced banks to develop more appropriate techniques such as gridpoint hedging. These (in today's eyes) traditional approaches stood the banks in good stead for the next decade. This chapter describes the main techniques of both gridpoint and curve hedging, taking into account both first and second-order sensitivities. In passing, mapping cashflows to gridpoints is also discussed. The use of swap futures, as a relatively new hedging instrument, is also considered. The chapter then extends risk management to interest rate options. Most texts discuss the "Greeks" using short-dated options; unfortunately the discussion often does not apply to long-term options, and so their different characteristics, especially as a function of time, are examined. The effectiveness of some optimisation techniques to construct robust hedges are examined as an alternative to the more traditional delta–gamma methods. Finally, the chapter shows how the same techniques can be used to create an inflation hedge for a portfolio of inflation swaps.

Chapter 13: Risk management however is not a static subject, but has evolved rapidly during the latter half of the 1990s and beyond. Traditional risk management operates quite successfully, but there is a very sensible desire by senior management to be able to assess the riskiness of the entire trading operation and even wider. The traditional risk measures are not combinable in any fashion and cannot be used. Value-at-Risk was developed as a family of approaches designed very much to address this objective. It is now being developed further to encompass not only market risk but also credit and even operational risks into the same set of measures.[1] This chapter describes the major approaches used to estimate VaR: delta, historic and Monte Carlo simulations, as well as second-order delta–gamma approaches. The advantages and disadvantages of each approach are discussed, along with various extensions such as extreme value theory and sampling strategies. The measurement of spread VaR and equity VaR using either individual stocks or a stock index are also considered. Finally, stress testing or how to make significant moves in the properties of the underlying risk factors (especially correlation) is described.

The book is supported by a full range of detailed spreadsheet models, which underpin all the tables, graphs and figures in the main text. Some of the models have not been described in detail in the text, but hopefully the instructions on the sheets should be adequate. Many of the models are designed so that the reader may implement them in practice without much difficulty.

Many of the ideas, techniques and models described here have been developed over the years with colleagues at both ANZ and Lombard Risk Systems, and through various consulting assignments with a wide range of banks across the world.

BIOGRAPHY

Richard Flavell has spent over twenty years working as a financial engineer, consultant and trainer, specialising in complex derivatives and risk management. He spent seven years as Director of Financial Engineering at Lombard Risk, where he was responsible for the mathematical development and implementation of models in its varied pricing and risk systems. He is currently Chairman of Lucidate, a company which specialises in the provision of consultancy and training to financial institutions.

[1] See the proposed Basel Accord (for details see the BIS website: *www.bis.org*) for the regulatory requirements using VaR-style approaches.

Worksheets

(*see* the accompanying CD inside the back cover)

Explanatory note: The vast majority of spreadsheets refer to a base spreadsheet called "Market Data". Under current Excel rules, this needs to be opened should the reader wish to save any model.

In most cases, there is one spreadsheet containing all the models for each chapter. The nomenclature is clear: for example, "Ch 2 Short-term Swaps" contains all the models for Chapter 2. There are however some exceptions, where some models are contained in separate spreadsheets. These usually involve models containing either optimisation or Monte Carlo simulation, when it is recommended that these models should be run with all other spreadsheets closed. This refers in particular to Chapters 8 and 11, running LPI and BGM simulations, respectively. The names of the individual spreadsheets are included in the list below:

2.1 Market data
2.2 Worksheet to calculate a discount factor from a set of cash rates
2.3 Worksheet to demonstrate the concepts of discounting
2.4 Worksheet to calculate forward rates from a set of cash rates
2.5 Worksheet to calculate a forward curve from a set of cash rates—II
2.6 Worksheet to use futures to calculate a FRA
2.7 Pricing a money market swap using futures and cash
2.8 Pricing a money market swap off a futures strip
2.9 The construction of a discount curve when futures are not evenly spaced—correcting for the date mismatches in the futures
2.10 Pricing a money market swap off a futures strip—version 2
2.11 Pricing a money market swap off a futures strip using forward valuing

3.1 Market data
3.2 Worksheet to generate the cashflows of a generic USD swap
3.3 Worksheet to demonstrate the discovery of a synthetic par bond
3.4 Worksheet to generate the fixed cashflows of a generic USD swap
3.5 Worksheet to calculate a discount curve using linear interpolation on the swap curve and different methods on the discount curve
3.6 Details of Hermitian interpolation
3.7 Worksheet to calculate a discount curve using Hermite interpolation on the swap curve and different methods on the discount curve
3.8 Worksheet to calculate a discount curve using an optimisation approach
3.9 Building a blended curve using optimisation

Spreadsheet "Ch 6 Credit-adjusted Pricing"

Spreadsheet "Ch 6 Appendix Modelling a Portfolio CDS"

Spreadsheet "Ch 7 Appendix Convexity Structures"

Spreadsheet "Ch 7 Measuring the Convexity Effect in an IRS Using BGM"

Spreadsheet "Ch 8 Cross-market and Other Market Swaps"

Spreadsheet "Ch 8 Inflation Swap Models"

Spreadsheet "Ch 8 Building an Inflation Curve by Optimisation"

Spreadsheet "Ch 8 Inflation Swap Models"

Spreadsheet "Ch 8 LPI Inflation Swap"

Spreadsheet "Ch 8 Inflation Swap Models"

Spreadsheet "Ch 8 Inflation—Seasonality Adjustments"

Spreadsheet "Ch 8 Cross-market and Other Market Swaps"

Spreadsheet "Ch 10 SABR Model"

Spreadsheet "Ch 11—Summary of Spreadsheets"
(lists the main spreadsheets for this chapter)

Spreadsheet "Ch 11 Modelling WB Accrual Note"

Spreadsheet "Ch 11.3 BDT Modelling a Swap"

Spreadsheet "Ch 11.10 Pricing and Calibrating a CMS"

Spreadsheet "Ch 11.22 Pricing a Callable Range Accrual"

Spreadsheet "Ch 11.28 Implying Forward–forward Volatilities

Spreadsheet "Ch 11.36 Example of BGM Simulation"

Spreadsheet "Ch 11.41 Example of Very Long-step BGM Simulation"

Spreadsheet "Ch 11.49 Modelling a Sticky Floater"

Spreadsheet "Ch 11.56 Modelling a TARN"

Spreadsheet "Ch 11.62 Modelling a Callable Snowball"

Spreadsheet "Ch 11.67 BDT with a Smile"

Spreadsheet "Ch 11.69 Hull and White Example"

Spreadsheet "Ch 11.80 BDT Pricing a Caplet and Some Swaptions"