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Measuring market risk

Second Edition

KEVIN DOWD

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Preface to the Second Edition

> You are responsible for managing your company's foreign exchange positions. Your boss, or your boss's boss, has been reading about derivatives losses suffered by other companies, and wants to know if the same thing could happen to his company. That is, he wants to know just how much market risk the company is taking. What do you say?
>
> You could start by listing and describing the company's positions, but this isn't likely to be helpful unless there are only a handful. Even then, it helps only if your superiors understand all of the positions and instruments, and the risks inherent in each. Or you could talk about the portfolio's sensitivities, i.e., how much the value of the portfolio changes when various underlying market rates or prices change, or perhaps option deltas and gammas. However, you are unlikely to win favor with your superiors by putting them to sleep. Even if you are confident in your ability to explain these in English, you still have no natural way to net the risk of your short position in Deutsche marks against the long position in Dutch guilders.... You could simply assure your superiors that you never speculate but rather use derivatives only to hedge, but they understand that this statement is vacuous. They know that the word 'hedge' is so ill-defined and flexible that virtually any transaction can be characterized as a hedge. So what do you say?[1]

The obvious answer, 'The most we can lose is...' is also clearly unsatisfactory, because the most we can possibly lose is everything, and we would hope that the board already knows that. Consequently, Linsmeier and Pearson continue, 'Perhaps the best answer starts: "The value at risk is..."'

So what is value at risk? Value at risk (VaR) is the maximum likely loss over some target period – the most we expect to lose over that period, at a specified probability level. It says that on 95 days out of 100, say, the most we can expect to lose is $10 million or whatever. The board or other recipients specify their probability level – 95%, 99% and so on – and the risk manager can tell them the maximum they can lose at that probability level. The recipients can also specify the horizon period – the next day, the next week, month, quarter, etc. – and again the risk manager can tell them the maximum amount they stand to lose over that horizon period. Indeed, the recipients can specify any combination of probability and horizon period, and the risk manager can give them the VaR applicable to that probability and horizon period.

We then have to face the problem of how to estimate the VaR. This is a tricky question, and the answer is very involved and takes up much of this book. The short answer is, therefore, to read this book or others like it.

However, before we get too involved with VaR, we also have to face another issue. Is a VaR measure the best we can do? The answer is no. There are alternatives to VaR and some

[1] Linsmeier and Pearson (1996, p. 1).

of these – especially the coherent risk measures – are demonstrably superior. Consequently, I would take issue with Linsmeier and Pearson's answer. 'The VaR is...' is sometimes a reasonable answer, but it is often not the best one and it can sometimes be a very bad one. Risk managers who use VaR as their preferred risk measure should really be using coherent risk measures instead: VaR is already passé.

But if coherent risk measures are superior to VaR, why bother to estimate VaR? This is a good question, and also a controversial one. Part of the answer is that there will be a need to estimate VaR for as long as there is a demand for VaR itself: if someone wants the number, then someone will want to estimate it, and whether anyone should want the number in the first place is another matter. In this respect VaR is a lot like the infamous beta. People still want beta numbers, regardless of the well-documented problems of the Capital Asset Pricing Model on whose validity the beta risk measure depends. A purist might say they shouldn't, but the fact is that they do. So the business of estimating betas goes on, even though the CAPM is now widely discredited. The same goes for VaR: a purist would say that VaR is an inferior risk measure, but people still want VaR numbers and so the business of VaR estimation goes on regardless. A second and better reason to estimate the VaR is that the VaR is a quantile (i.e., a quantity associated with a particular cumulative probability), and there are sometimes good reasons to estimate quantiles. For example, we might want to estimate quantiles when dealing with what insurers call 'probability of ruin' problems, where we are interested in a threshold that will be exceeded with a certain probability. Such problems occur very commonly, most particularly when it comes to the determination of reserves or capital requirements. However, there is also a third and more general reason to estimate VaRs: being able to estimate a VaR (or a quantile) is the key to the estimation of better risk measures, since the coherent and other risk measures are essentially weighted averages of quantiles. So we need to be able to estimate quantiles, even if we don't wish to use VaR as our preferred risk measure.

INTENDED READERSHIP

This book provides an overview of the state of the art in market risk measurement. The measures covered include the VaR, but also include coherent risk measures as well. Given the size and rate of growth of this literature, it is impossible to cover the field comprehensively, and no book in this area can credibly claim to do so, even one like this that focuses on risk measurement and does not try to grapple with the much broader field of market risk management. Within the subfield of market risk measurement, the coverage of the literature provided here can claim to be no more than reasonably extensive.

The book is aimed at three main audiences. The first consists of practitioners in risk measurement and management – those who are developing or already using VaR and related risk systems. The second audience consists of students in MBA, MA, MSc and professional programmes in finance, financial engineering, risk management and related subjects, for whom the book can be used as a reference or textbook. The third audience consists of PhD students and academics working on risk measurement issues in their research. Inevitably, the level at which the material is pitched must vary considerably, from basic to advanced. Beginners will therefore find some of it heavy going, although they should get something out of it by skipping over difficult parts and trying to get an overall feel for the material. For their part, advanced readers will find a lot of familiar material, but even many of them should, I hope, find some material here to interest them.

To get the most out of the book requires a basic knowledge of computing and spreadsheets, statistics (including some familiarity with moments and density/distribution functions), mathematics (including basic matrix algebra), and some prior knowledge of finance, most especially derivatives and fixed-income theory. Most practitioners and academics should therefore have relatively little difficulty with it, but for students this material is best taught after they have already done their quantitative methods, derivatives, fixed-income and other 'building block' courses.

USING THIS BOOK

In teaching market risk material over the last few years, it has also become very clear to me that one cannot teach this material effectively – and students cannot really absorb it – if one teaches only at an abstract level. Of course, it is important to have lectures to convey the conceptual material, but risk measurement is not a purely abstract subject, and in my experience students only really grasp the material when they start playing with it – when they start working out VaR figures for themselves on a spreadsheet, when they have exercises and assignments to do, and so on. When teaching, it is therefore important to balance lecture-style delivery with practical sessions in which the students use computers to solve illustrative risk measurement problems.[2]

If the book is to be read and used practically, readers also need to use appropriate spreadsheet or other software to carry out estimations for themselves. Again, my teaching and supervision experience is that the use of software is critical in learning this material, and we can only ever claim to understand something when we have actually calculated it ourselves. The calculation and risk material are intimately related, and the good risk practitioner knows that the estimation of risk measures always boils down to some spreadsheet or other computer function. In fact, much of the action in this area boils down to software issues – comparing alternative software routines, finding errors, improving accuracy and speed, and so on. A book on risk measurement should therefore come with some indication of how risk measurement routines can be implemented on a computer.

It is better still for such books to come with their own software, and this book comes with a CD that contains a selection of risk measurement and related functions in MATLAB (and some Excel ones too) and a manual explaining their use.[3] My advice to users is to print out the manual and go through the functions on a computer, and then keep the manual to hand for later reference.[4] The examples and figures in the book are produced using this software, and readers should be able to reproduce them for themselves. Readers are very welcome to contact me with any feedback. I will keep the Toolbox and the manual up to date on my website (www.nottingham.ac.uk/~lizkd), and readers are welcome to download updates from there.

In writing this software, I should explain that I chose MATLAB mainly because it is both powerful and user-friendly, unlike its obvious alternatives (VBA, which is neither powerful

[2] For those who wish to use this book for teaching, I also have a complete set of Powerpoint slides, which I am happy to make available on request.

[3] MATLAB is a registered trademark of The MathWorks, Inc. For more information on MATLAB, please visit their website, www.mathworks.com.

[4] The user should copy the Managing Market Risk folder into his or her MATLAB works folder and activate the path to the Managing Market Risk folder thus created (so MATLAB knows the folder is there). The functions were written in MATLAB 6.0 and most of the MMR functions should work if the user has the Statistics Toolbox as well as the basic MATLAB 6.0 or later software installed on their machine. However, a small number of MMR functions draw on functions in other MATLAB toolboxes (such as the Garch Toolbox), so users with only the Statistics Toolbox will find that the occasional MMR function does not work on their machine.

nor particularly user-friendly, or the C or S languages, which are not so user-friendly). I also chose MATLAB in part because it produces very nice graphics, and a good graph or chart is often an essential tool for risk measurement. Unfortunately, the downside of MATLAB is that many users of the book will not be familiar with it or will not have ready access to it, and I can only advise such readers to think seriously about going through the expense and/or effort to get it.[5]

In explaining risk measurement throughout this book, I have tried to focus on the underlying ideas rather on programming code: understanding the ideas is much more important, and the coding itself is mere implementation. My advice to risk measurers is that they should aim to get to the level where they can easily write their own code once they know what they are trying to do. However, for those who want it, the code I use is easily accessible – one simply opens up MATLAB, goes into the Measuring Market Risk (MMR) Toolbox, and opens the relevant function. The reader who wants the code should therefore refer directly to the program coding rather than search around in the text: I have tried to keep the text itself free of such detail to focus on more important conceptual issues.

The MMR Toolbox also has many other functions besides those used to produce the examples or figures in the text. In fact, I have tried to produce a fairly extensive set of software functions that would cover all the obvious estimation measurement problems, as well as some of the more advanced ones. Users – such as students doing their dissertations, academics doing their research, and practitioners working on practical applications – might find some of these functions useful, and they are welcome to make whatever use of these functions they wish. However, they should recognise that I am not a programmer and anyone who uses these functions must do so at his or her own risk. As always in risk management, we should keep our wits about us and not be too trusting of the software we use or the results we get.

OUTLINE OF THE BOOK

The first chapter provides a brief overview of recent developments in risk measurement, and focuses particularly on the remarkable rise to prominence of the VaR in the 1990s. This puts VaR into context, and also explains the attractions that made it so popular. Chapter 2 then looks at three different risk measurement frameworks, based respectively on portfolio theory, VaR and coherent risk measures. This chapter is in many ways the key chapter in the book, and sets out in considerable detail what is wrong with the VaR and why coherent risk measures are superior to it.

Having established what our basic risk measures actually are, Chapter 3 provides an introduction to and overview of the main issues involved in estimating them. Later chapters then fill in some of the detail:

- Chapter 4 discusses the non-parametric approaches, in which we seek to estimate measures of market risk while making minimal assumptions about the distribution of losses or returns.
- Chapter 5 looks at the forecasting of volatilities, covariances and correlations, which are a preliminary to the parametric approaches that follow.

[5] When I first started working on this book, I initially tried writing the software functions in VBA to take advantage of the fact that almost everyone has access to Excel; unfortunately, I ran into too many problems and eventually had to give up. Had I not done so, I would still be struggling with VBA code even now, and this book would never have seen the light of day. So, while I sympathise with those who might feel pressured to learn MATLAB or some other advanced language and obtain the relevant software, I don't see any practical alternative: if you want software, Excel/VBA is just not up to the job – although it can be useful for many simpler tasks and for teaching at a basic level.

- Chapters 6 and 7 discuss the parametric approaches, which estimate risk measures based on assumptions about loss or return distributions. Chapter 6 looks at general parametric approaches and Chapter 7 looks at extreme-value (EV) approaches.
- Chapters 8 and 9 discuss Monte Carlo simulation (or 'random number') methods, with Chapter 8 providing an introduction to these methods in general, and Chapter 9 examining some of the many ways in which these methods can be used to estimate market risk measures. These are immensely powerful methods that can handle a very large range of problems, including very complicated ones.
- Chapter 10 examines the difficult but important subject of how to estimate risk measures for options positions.
- Chapter 11 discusses risk decomposition: how to 'break down' aggregate risk measures and allocate risk to individual positions in our portfolio.

The remaining chapters look at various other important topics related to the estimation of market risk measures:

- Chapter 12 discusses the subject of mapping, where 'real' positions are 'mapped' to surrogate ones that are much easier to handle. We can also think of mapping as the process of describing our positions in terms of combinations of standard building blocks.
- Chapter 13 examines stress testing (or 'what if' analysis). Stress tests are important complements to probabilistic risk measures, and can also be regarded as bona fide risk measures in their own right.
- Chapter 14 discusses the multifaceted issue of liquidity risk: the nature of market liquidity, how to modify estimates of risk measures to allow for it, how to estimate liquidity at risk, and how to estimate crisis-related liquidity risks.
- Chapter 15 deals with backtesting – the application of quantitative methods to determine whether a model's risk estimates are consistent with the assumptions on which the model is based or to rank models against each other.
- Finally, Chapter 16 considers the important subject of model risk – the risk of error in our risk estimates due to inadequacies in our risk models.

REVISIONS TO THE SECOND EDITION

The second edition represents a very substantial revision to the first. There is some updating and I have made a major effort to take into account not only the mainstream financial risk literature, but also the actuarial/insurance literature, which has many useful contributions to offer. To make space for the new material, I have also cut out material on topics (e.g., on quasi-Monte Carlo and lattice methods) that have yet to make a major impact on the risk measurement literature: the new edition is meant to reflect the state of practice, and I have (in places, at least) tried to resist the temptation to put in material that is yet to be widely accepted by the risk management profession. The only real exception is in Chapter 15 on backtesting, but much of the new material in this chapter is based on my own recent research and has already been through considerable scrutiny through the journal refereeing process.

In terms of the argument 'pushed' by the book, I have to admit that I am very much persuaded by arguments made for the superiority of coherent risk measures over the VaR, and I am increasingly conscious of the limitations of the latter. In fact, I have pretty much persuaded myself by now that the VaR is close to useless as a 'proper' risk measure, although that is not to say that the VaR as such is useless, because it also has its uses as a quantile. However, I also

believe that there are major issues with coherent risk measures too: they are far from 'perfect' themselves, and there are many unanswered questions about them. At a deeper level, I also believe that there are major problems with the application of physical science models to social situations, and I remain extremely sceptical of the financial regulatory system, which I believe does more harm overall than good.

The material itself is radically reorganised in the light of feedback, further teaching experience and the like, and I have put in a large number of worked-out examples which show how many of the calculations can be carried out from scratch. There is therefore a much greater emphasis on worked-out examples and on explaining the principles and mechanics of the calculations.

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Contents

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