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Statistical Methods for Financial Engineering

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x+496 pp.

In the narrow Wall Street interpretation, *financial engineering* refers to the creation of more specialized financial securities out of more fundamental assets such as collections of stocks, bonds, currencies, or mortgages. Used this way, the term now inevitably evokes memories of the mortgage pool "tranches" that became famous during the financial crisis of 2008–2009. In this instance, the payment stream from an ensemble of lower quality mortgages was divided into separate sub-streams that were sold individually as newly created fixed income securities. The sum of the parts could then be valued at more than the whole because some of the constructed streams could qualify for higher-grade credit ratings than the original pool.

In the beginning at least, there was genuine value added through this engineering, but history was not kind to these inventions. As the housing crisis evolved, the market for these products essentially froze, financial institutions suffered record breaking-losses, and much blame was directed toward financial engineers. The world has now mostly recovered from the crisis, and tempers have cooled, but it is still fair to say that some engineered products did not work as expected.

There is a broader interpretation of *financial engineering* that is more academic, more statistical, and more relevant to Rémillard's interesting new book. In this interpretation one takes the fundamental topics of mathematical finance and addresses those topics from an "engineering perspective" of practical methods and algorithms rather than the nuances of mathematical or economic rigor. In fact, this text is organized much like an engineering handbook where a large number of models and methods are presented succinctly, and their salient features are reviewed with a minimum of fuss. The organization is also highly modular. Each chapter is essentially independent of the others, and each has its own bibliography and its own appendices. Most proofs and technical discussions are found in these appendices.

The book begins with three chapters on the Black-Scholes model, and these move quite quickly. It is taken for granted that the reader is comfortable with Brownian motion and the language of stochastic calculus. A reader who is familiar with Björk (1999) or Mikosch (1999) would be suitably prepared, but it would be hard to get by with much less. An innovative feature of these chapters is the inclusion of the simulation method of Broadie and Glasserman (1996) for estimation of the "Greeks," or the parameter elasticities for option prices.

These chapters also set the tone for much of the text. For example, there are MATLAB exercises, and one finds interesting tidbits of engineering practice. For example, there is the suggestion to use $T = 252$ for the number of days T in the year when applying the Black-Scholes model. There is also an instructive side-bar box (p. 64) that gives a simple non-Gaussian example that shows that the Ljung-Box test for auto-correlation is inconsistent; this is certainly not widely known, though it might not matter in the context where the Ljung-Box test is commonly applied.

The fourth chapter addresses methods for measurement of risk and methods for measurement of performance. These topics are more commonly viewed as being in different worlds, but there is some logic to treating them together. A central concept of the current technology for risk management is that of VaR, or *value at risk*, but one could not tell from this chapter that the practical merit of VaR is hotly debated in the financial community. The fundamental problem with estimates of VaR is that they are based on past data and therefore backward-looking. A non-financial statistician might ask, "What else could one do?", but this is not a well-informed question; it ignores the distinction between "observed risks" and "unobserved risks." This much-studied distinction is one facet of what economists call the *Peso problem*, see e.g. Lewis (2008).

By no means does the absence of observed historical risk imply that real economic risk is not present. In fact, the very low rate of mortgage defaults leading up to 2006 is now seen as one of the *causes* of the higher rates of mortgage defaults after 2006. This chapter does not engage these issues; instead, it sticks to its handbook treatment of the traditional technology for VaR. This is useful as far as it goes, but it would have been a valuable service to alert a possibly naïve reader to the not-yet-observed icebergs in the water. For a broad, non-technical treatment of VaR that includes some interesting history and many references, one can consult Damodaran (2014).

Chapters 5 and 6 are more eclectic. The first of these reprises the conventional methods for modeling interest rates including the Vasicek (or Ornstein-Uhlenbeck model) and the Cox-Ingersoll-Ross (or Feller) model. The second of these chapters reprises in a similar way several of the most widely discussed price models that are driven by Lévy process. Perhaps the most novel feature of the chapter is its inclusion of the interesting but understudied jump-diffusion model of Kou (2002).

Chapter 7 takes up the stochastic volatility models, especially the GARCH "zoo" with the usual suspects: GARCH (p,q), EGARCH, NGARCH, GJR-GARCH. For a classroom treatment of this classic material, one would probably find that the text of Lai and Xing (2008) would work more smoothly, but a pleasing novelty here is the pointer to the interesting augmented GARCH model of Duan (1997). Finally, the chapter has a succinct discussion of the Hesten model, and an appendix recalls relevant formulas involving characteristic functions. The latter includes a discussion of the Gil-Peleaz formula (p. 139) that is stimulating — but arguably over optimistic. This formula does give a tidy integral representation for the distribution function, but the representing integral must be interpreted as a Cauchy principal value. This introduces technical difficulties that usually outweigh the benefits of brevity.

Chapter 8 on "Copulas and Applications" is one of the text's longest and most conventional chapters. The chapter is perfectly serviceable, but it could have been enriched by being more forthcoming about the alleged role of copulas in the financial crisis. Anyone who teaches about the applications of copulas will be missing out on a well-received lecture unless the tale is told of David Li and his default correlation model, Li (2000). Rémillard does mention Li's model (p. 262), but no hint is given there of the drama that press treatments such as Salmon (2003) or Jones (2009) have attributed to this modest, straightforward application of the Gaussian copula. Behind any story is always a richer story (e.g. Embrechts, 2009), but job-seeking students with copulas in their portfolio would do well to have some idea of this famous context.

Chapters 9 and 10 are also largely conventional treatments of filtering and its application to linear statistical models such as ARMA(p,q). The most novel inclusion is an application to "Hedge Fund Replication," which here just means the creation of a combination of two risky streams of returns to mimic as closely as possible the returns of a third risky stream. This is an interesting problem that can be framed in many ways. Filtering seems to have a natural role, but one can also gain substantial insight with just plain vanilla regression, see e.g. Hasanhodzica and Lo (2007).

The book ends with two further appendices on basic probability and mathematical statistics; these take up 47 of the text's 462 pages. It is hard to believe that these pages add value to a reader who can read past the first chapter, but perhaps some readers may find their presence reassuring. One can hope that in the future, more authors will have more confidence that *Wikipedia* can be trusted to give readers handy access to such basic information.

In summary, this is an interesting book with many features that are not easily found elsewhere. One may wish for more skepticism, more history, or more discussion of stylized facts, but a well-informed reader will still find enough new material here to justify the purchase. In particular, libraries will certainly want to acquire a copy.

The classroom use of this book is more problematical. This is not a book for beginners in financial engineering. To follow the thread, one needs a decent background in stochastic processes, time series, and mathematical statistics. To make honest use of the book one also needs some experience with financial markets, market history, and at least some experience with the stylized facts of asset returns, see e.g. Cont (2001). Finally, the reader should be content with an organization that is more like a handbook than a traditional classroom text. By necessity, much of the treatment is conventional, but there are plenty of points at which even experts will pick up new ideas.

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