A Review of Recent Books on Credit Risk

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The usual risk taxonomy has three types: market risk, credit risk and operational risk. Market risk arises from the movements in the level or volatility of market prices. Credit risk is the risk that an obligor (borrower, counterparty) may be unable or unwilling to repay their debt, and operational risk, which is broadly a residual category, is specified as the risk of direct or indirect loss resulting from inadequate or failed internal processes, people and systems or from external events.[1] Credit risk makes up about $50-60\%$ of the total risk in a typical, large bank, with market risk taking a smaller share ($\sim 20\%$) of the remainder than operational risk (Kuritzkes, Schuermann and Weiner (2003)). A securities firm or investment bank will likely have relatively more market than credit risk, while insurers are somewhere in between. Yet the bulk of academic research has focused on market risk, perhaps because data is plentiful and easy to obtain, while credit risk has received less attention in the literature, until recently. Indeed we have seen a veritable explosion of research over the past few years as the well established tools of pricing and portfolio management find their way to that vast realm of relatively illiquid credit assets. It has attracted a diverse group of disciplines, from traditional finance (asset pricing) to mathematical statistics to econometrics. And because credit risk is the dominant risk for banks, regulators pay particular attention to its measurement and management. Recently this has culminated in the proposed New Basel Capital Accord (BIS (2001, 2003)), a radical restructuring of how credit risk is assessed and capital set against it.[2]

In this review I cover three books on credit risk which have appeared recently, though these are far from the only books on this topic. However, they do represent in my view the best of the crop and illustrate the diverse set of issues and their treatments which have occupied the literature, both academic and practitioner. The review is organized around some of the key questions and themes of this literature and how they are addressed by these authors.

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[1] This definition is used in the New Basel Capital Accord (BIS (2001), §547).

[2] The purpose of capital is to provide a cushion against losses for a financial institution. The literature on the general rationale for capital regulation in financial institutions is extensive and has been the subject of several recent surveys (Santos (2001), Ball and Stoll (1998), Berger, Herring and Szegö (1995)).

The books are (in the usual alphabetical order):

- Darrell Duffie and Kenneth J. Singleton (2003), *Credit Risk: Pricing, Measurement and Management*, Princeton, NJ: Princeton University Press.
- David Lando (2004), *Credit Risk Modeling: Theory and Applications*, Princeton, NJ: Princeton University Press.
- Philipp J. Schönbucher, (2003), *Credit Derivatives Pricing Models: Models, Pricing and Implementation*, New York, NY: John Wiley & Sons.

All authors are academics with extensive practitioner contact through consulting engagements. Duffie & Singleton as well as Lando provide a carefully crafted balance between formal rigor and breadth and readability, while Schönbucher's treatment tends to be somewhat more mathematical in nature. Schönbucher's book is, as the title suggests, more narrowly focused on credit derivatives, the financial engineering innovation for managing credit risk. This important tool, treated to some degree by the other books, is covered below in Section 3. First, in Section 2 we explore credit risk at the micro (firm, asset) level before considering the macro (portfolio, global) level. The review will wrap up in Section 4 by considering some shortcomings and some final thoughts.

All three books provide a clear and technical discussion of the main issues and tools needed to address them. The reader looking for a broader introduction to the topic, with more discussion of the regulatory context and industry models and practice, should consider a text such as Saunders and Allen (2002).

1 Credit Risk: Micro

The cornerstone problem of credit risk is modeling the default likelihood of the obligor or borrower. This probability of default (PD) drives almost everything else, from pricing to portfolio management to capital allocation (regulatory or otherwise). Chapter 3 in Duffie & Singleton and Chapter 4 in Lando address this issue more (Lando) or less (Schönbucher) thoroughly. Many of the concepts and models translate to individuals rather than firms, but for simplicity, and because this is the dominant phenomenon, this discussion will focus on firms. To help fix ideas, let PD_{it} be the probability of default for firm i at time t, driven by a set of firm-level characteristics, some of which are fixed in time (like industry), denoted by z_i, some of which change over time (like profitability) denoted by x_{it}, and a set of systematic factors which affect all firms (like interest rates), denoted by y_t :

$$PD_{it} = f\left(z_i, x_{it}, y_t; u_{it}; \theta\right) \tag{1}$$

where the mapping function $f(\cdot)$ may be fixed or time-varying, θ collects all of the relevant parameters (these could vary over firms), and u_{it} loosely represents innovations or shocks, which could

be a composite of systematic (coming, say, from the distribution of y_t) and idiosyncratic shocks. The firm may be privately held or publicly traded. If the latter, then disclosure and reporting requirements render the otherwise rather opaque firm significantly more transparent, though recent experience (e.g. Enron, WorldCom, and others) has reminded us that lots of firm level data does not always equate to good information. All three books focus their attention largely (Duffie & Singleton, Lando) or exclusively (Schönbucher) on the case where publicly traded instruments such as bonds or stocks are available.

Estimating (1) can be quite complicated. For starters, defaults are rare: the overall annual default rate of S&P rated firms from 1981-2003 was 1.68%, and only 0.24% for investment grade firms (BBB-/Baa3 or better). Second, the number of candidate variables in z_i and x_{it} can be quite large, with several similar ways of describing profitability, for example, and little theory to provide guidance on selection. Third, since defaults are rare, they are usually gathered over a long time span (several years), but then merged with non-defaulted firm data from recent history (say within the last year). Naturally the economic conditions faced by the two sets may be quite different. Fourth, in addition to possible time variation, $f(\cdot)$ could vary substantially by industry (e.g. agriculture vs. financial services) or country (for example, firms in Germany and Japan are traditionally more highly leveraged than in the U.S. or U.K). Fifth, y_t may have complicated business cycle dynamics whose modeling is required for forecasting PD_{it}. Finally, unobserved firm heterogeneity may be quite important, manifested through θ_i as well as the distribution of u_{it}.

Since default prediction is such a fundamental problem, a rich set of solutions has emerged, and they differ often quite fundamentally, depending on the information broadly and data more narrowly that is available. If a sample containing actual defaulted firms and (similar) non-defaulted firms is available, a host of direct methods are available, from discriminant analysis, as in the pioneering work of Altman (1968), discussed in Lando, Section 4.2, logistic regression (in Lando, Section 4.1) or duration modeling (e.g. Shumway (2001)), in Lando, Sections 4.3 and 4.4, and other approaches such as neural networks (see Saunders and Allen (2002) for a review and comparison). Duffie & Singleton cover this material briefly in Section 3.7. The issue of information asymmetry between the lender and the borrowing firm, which knows presumably more about its financial health than the lender, receives surprisingly little attention in all of the texts; we will come back to this important issue

Suppose now that we have a set of firms with publicly traded instruments such as stock (equity shares) or bonds. Not only do we now have quarterly and annual reports to rely on, but we have the market digesting this information and expressing its view through the stock price. If in addition the firm has issued public debt, we have market information on bond or credit spreads and the opinion of a third party, namely a credit rating agency, on the creditworthiness of this firm. It is this last case, credit spreads with third party information, which forms the bulk of modeling in the literature, and consequently in these three books.

At this juncture it is worthwhile introducing a model taxonomy used by all three sets of authors which is quite common in the literature: structural vs. reduced form models. To a traditional econometrics audience these terms have very specific meaning, e.g. in simultaneous equations modeling of, say, supply and demand relationships. Here the meaning is similar. Structural models start with a firm's balance sheet, debt and equity structure, and the evolution of firm value. These are used to say something about individual firm default and the pricing of debt (or credit). Reduced form models take as their starting point this debt price, or credit spread, and infer from this, without knowledge of the firm's inner (balance sheet) structure, credit risk information such as default probabilities.

An important structural model which has had enormous influence is the option theoretic default model due to Merton (1974). Merton recognized that a lender is effectively writing a put option on the assets of the borrowing firm; owners and owner-managers (i.e. shareholders) hold the call option. If the value of the firm falls below a certain threshold, the owners will put the firm to the debt-holders. Thus a firm is expected to default when the value of its assets falls below a threshold value determined by its liabilities. Two aspects need modeling: the evolution of firm value, where a key parameter is the (asset) return volatility, and the default threshold.

Duffie & Singleton in particular lay out very carefully the array of models which deal with pricing of corporate debt. Chapters 5, 6 and 7 deal largely with this topic. Both authors have individually and together written important papers on this topic (Duffie and Singleton (1999) is an often cited example), and Singleton's long and influential record of research on term structure models (see, for example, Dai and Singleton (2003)) shines through, both in the main chapters of their books as well as the technical appendix.

Lando's book is notable in that it starts off right away with the Merton (structural) model and subsequent refinements in Chapters 2 and 3, and he does a marvelous job at carefully and thoroughly explaining their differences and nuances. Duffie & Singleton's treatment is less well organized, as we encounter these models in a piecemeal fashion throughout the book, starting briefly in Chapter 3, more extensively in Chapter 5, and again in Chapter 7. A similar comment could be made about Schönbucher's discussion of these models.

Reduced form pricing models have strong intellectual linkages to no-arbitrage (risk-free) yield curve models. These models are often written in continuous time, and so it is no surprise that default is typically modeled as an intensity or an instantaneous probability of default. There are two other key parameters which are fit (or calibrated) to the data: loss severity (or recovery) and the market price for risk or the risk premium. After all, an investor is paid only to hold systematic, not idiosyncratic risk as that can be diversified away. Since default timing and recovery are uncertain, and moreover since they are correlated with the business cycle, a premium is demanded to hold on to that risk. Duffie & Singleton's and Lando's treatment of this material is first rate, a prime example being the discussion of risk neutral vs. physical default probabilities connected by the risk premium

(Chapter 5 in both Duffie & Singleton and Lando), with Lando's discussions being a bit more reader-friendly. Indeed Lando has a gift for explaining this often complicated material to the non-expert. As with the structural models, these two books have taken a different organizational strategy in presenting the material. Duffie & Singleton weave these models throughout their discussion of the topics – first introduced in Chapter 3 (Section 3.4), compared to structural models in Chapter 4, and then worked into pricing models in Chapters 6 and 7.

Schönbucher's provides the most formal treatment of this material, but at the same time reminds the reader throughout of institutional nuances and subtleties well known to practitioners but often abstracted away by academics. Perhaps one example is his excellent discussion of which risk-free rate (or curve, as in yield curve) to use when pricing credit risky instruments. One might say: why, the Treasury (or government) bond curve, of course. Schönbucher argues elegantly in Section 3.6.1 why this is not necessarily the case in practice. He also goes to great lengths, arguably more than the other texts, in meticulously describing the implementation of the intensity-based models, devoting a whole chapter (Chapter 7) to this topic.

2 Credit Risk: Macro

If the default probability is the cornerstone of micro-credit risk, default correlation is its counterpart in macro-credit risk. Consider now the case of a credit or loan portfolio in contrast with an individual bond or loan. Or alternatively one might have a small portfolio of assets bundled together into a CDO (collateralized debt obligation). As a result I might not worry principally about the default behavior of any one asset but rather the default and loss behavior of the entire portfolio. To some degree this simplifies the problem considerably, and indeed a popular result by Vasicek (1987, 2002) shows how the portfolio loss distribution can be derived in closed form given only two parameters: the average default probability of the individual firms, say $\overline{PD}$, and their average asset correlation, $\bar{\rho}$.

The structural vs. reduced form modeling paradigm from asset-level risk carries over to some degree to default dependence in portfolios. In structural models, firm returns and defaults are tied together through the systematic factors y_t, whereas in reduced form models default dependence is modeled directly via correlated intensities, either with or without correlated jumps (or specific credit events). Duffie & Singleton and Lando treat this complex topic thoroughly, although I found Lando's discussion to be clearer and easier to follow.

All three texts devote an entire chapter exclusively to the topic of correlated defaults, (Chapter 10 in Duffie & Singleton, Chapter 9 in Lando and Chapter 10 in Schönbucher), although Lando and Schönbucher leave the discussion to the end of their books which I found puzzling. However, they make up for it with an excellent discussions of the notion of conditional independence underlying the structural models: conditional on y_t, the default likelihood of firm i is independent of firm j.

A single-factor (y_t is a scalar) version underlies the New Basel Capital Accord, and Schönbucher carefully explains the extensions to multi-factor models (y_t is a vector) as well as different estimation approaches (Section 10.4.7): direct estimation and simulation. The source and dynamics of default dependence arises through the "factor loadings" which may differ across firms, and the dynamics and cross-dependence of the factors themselves (e.g. through a VAR of the business cycle factors if y_t is a vector). Sadly none of the texts had any discussion of what to do with dynamically evolving, or serially dependent, macro-variables, international business cycle dependence, crucial for the portfolio of large, internationally active financial institutions, or the impact of firm heterogeneity in factor loadings and/or default thresholds.

There are other approaches to modeling default correlations. Necessity is the mother of invention, or at least of re-invention. The credit risk literature has recently unearthed an old tool from statistics: the copula. The essential idea of the copula approach is that a joint distribution can be factored into the marginals and a dependence function called a copula, where the copula "couples" the marginal distributions together to form a joint distribution. The dependence relationship is determined by the copula, while scaling and shape (mean, standard deviation, skewness, and kurtosis) are determined by the marginals. In particular, not only does it allow for the merging of heterogeneous marginals, but the dependence concept is more generally applicable than the linear Pearson correlation coefficient. For example, certain copulas (e.g. the Student-t but not the Gaussian copula) allow for tail dependence. Schönbucher has done a lot of work in this area; he devotes more space to this topic than the other texts. Duffie & Singleton are more skeptical of this approach as a panacea for the default correlation problem, pointing out that theory gives us practically no guidance on the choice of copula and worse, few tools to evaluate the merits of different copulas. Still, the idea and tool is simple and compelling enough to invite the curious reader to learn more about it.

3 Credit Derivatives: Buying and Selling Credit Risk

The discussion so far has shown how to evaluate the risk of a particular credit to a particular firm, and how to aggregate those credit exposures into a portfolio and understand the risk characteristics of that portfolio. But how can one actively manage that portfolio through buying, selling and hedging? What should one buy, i.e. where should one increase my exposure? What should one sell, and can one sell these illiquid assets? Could one hedge out some of the credit risk?

While the first of those issues (buy) is relatively straight forward, the last two (sell, hedge) are not. Fortunately the financial engineers have been busy and productive, and it would be hard to exaggerate the importance of some of these risk management and mitigation tools: credit derivatives and collateralized debt obligations, CDOs. Default correlation lies at the heart of each of these decisions. Indeed credit derivatives are the financial instrument which tie together all of the credit

risk concepts and modeling approaches.

The growth of the credit derivative market has been extraordinary over the last seven to eight years. The British Bankers' Association's (BBA) recent biannual survey indicated that the notional volume, globally, increased from $180bn in 1997 to $1.95tn in 2002 (BBA (2002)). Of interest is also who are the buyers (seller) and sellers (buyers) of credit risk (credit protection). Commercial banks and securities houses together transferred about $350bn of credit assets out of their institutions, while insurers assumed over $500bn of credit assets in 2001 alone (BBA (2002)). Fitch (2003) broadly confirms these findings and reports further that U.S. commercial banks are net exporters of credit risk abroad. In short, credit derivatives, broadly defined, enable financial institutions to trade credit assets and hence credit risk across sectoral and national boundaries.

The CDO has helped to open up an otherwise highly illiquid asset class, namely loans (and thinly traded bonds). By bundling together 50 to 100 assets from as many firms (or names in the industry argot), tranching the return stream (effectively segmenting or dividing the return and/or loss distribution of that portfolio), and seeking an easily understood credit rating from one of the rating agencies, banks and other financial intermediaries are able to buy and sell credit exposure to a broader set of investors than ever before. More supply of credit assets, more demand for credit assets.

Schönbucher provides us with the most extensive discussion of these instruments, both in describing the sheer breadth of products and their pricing. While credit derivatives are treated late in the other books, Schönbucher devotes Chapter 2 entirely to explaining the different products. To the novice in the credit risk field this is a bit disconcerting since it is not clear at this stage of the book why these products are important and how they fit into the broader credit risk picture. But if a detailed and careful treatment of credit derivatives are what is desired, there may be no better place to look than Schönbucher's book. By contrast, Lando's treatment is surprisingly brief and happens before the default correlation chapter. Duffie & Singleton devote an entire chapter, clear and well written, just to CDOs, with excellent descriptions of the structuring and tranching of these instruments.

4 Final Comments

So far, so good, but where do the books fall short? There are two issues which I was surprised to see receiving rather little attention: 1) how poorly the credit risk models explain observed credit spreads, and 2) the role of asymmetric information and agency problems between borrower and lender.

Decomposing the credit spread has been the subject of a lot of research of late, starting perhaps with Elton, Gruber, Agrawal and Mann (2001), and more recently in Eom, Helwege and Huang (2004) and Huang and Huang (2004). Broadly speaking, the credit or yield spread above the

(default) risk-free rate of interest can be expressed as a function of the probability of default as in (1), optionality implicit (or explicit) in the debt instrument such as, for instance, early callability, the corporate tax rate,[3] and liquidity. The authors above report that the proportion of the credit spread attributable solely to default risk can be as small as 20% but can go as high as about 80% for high-yield bonds. Eom, Helwege and Huang (2004) in particular document the inaccuracy of credit spread forecasts from a host of models they test.

Given the non-trivial wedge between empirically observed credit spreads and actual default risk, this topic receives surprisingly little attention in any of the texts reviewed here. Lando, for instance, only informs the reader in the Bibliographic Notes sections (e.g. Section 2.4) rather than feature this issue more prominently in the chapters. Schönbucher has a very brief discussion in Section 9.6.1.4, whereas Duffie & Singleton make reference to this problem throughout their book. Duffie & Singleton is also the only text which covers the pricing of credit risky sovereign debt which have peculiar characteristics arising from the ambiguous nature of the "bankruptcy" event.

The second point on information asymmetries and agency problems between borrower and lender is perhaps more troubling. The argument is roughly as follows. A firm, particularly if it is young and privately held, knows more about its health, quality and prospects than outsiders, e.g. lenders. Banks are particularly well suited to help overcome these informational asymmetries through relationship lending; learning by lending. Moreover, managers and owners of firms have an incentive to substitute higher risk for lower risk investments as they are able to receive upside gains (they hold a call option on the firm's assets) while lenders are not (they hold a put option); see the survey by James and Smith (2000) for a more extensive discussion, as well as Garbade (2001).[4] Through careful, albeit costly, monitoring the bank learns more about its borrower than would a typical outsider, e.g. a bondholder. This is also one reason why loans trade at a premium to bonds from the same obligor, despite a likely liquidity discount.[5] If it is difficult for a bank with a lending relationship to learn about its counterparty, it is even harder to value a firm at arms length, even if that firm has publicly traded shares and bonds. Being able to look inside the black box that is the firm/obligor/counterparty is critical to modeling the evolution of firm value as well as the default threshold, the two main components of a default model. Credit ratings from rating agencies, being neither buyers nor sellers of credit assets, have the potential of playing an important, albeit crude, informational role, especially since in assigning their rating, they typically have access to private (inside) information on the firm they are rating (see Pesaran, Schuermann, Treutler and Weiner (2003)).

To be fair, Lando touches on this topic more than the other two books by devoting a short

[3] Corporate bonds have a tax disadvantage relative to treasury and municipal bonds, the latter also being subject to default.

[4] Neither of these references are mentioned in the three books reviewed here.

[5] Another important reason is that bank loans are typically first in line in the event of a bankruptcy.

chapter to models of strategic default (Chapter 3, "Endogenous Default and Optimal Capital Structure"). Duffie and Lando in their 2001 *Econometrica* paper dealt with the issue of noisy or incomplete balance sheet information. Indeed they show how, in the context of insiders being privy to private information, reduced form, intensity based models are actually fully consistent with structural, balance sheet based model.

With a menu of such rich offerings in credit risk modeling, it is hard to pick a favorite. No scholar or practitioner in the exciting area of credit risk should be without these books.

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