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Credit Markets: Retrospect and Prospect

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INTRODUCTION

As recently as the late 1980s, credit risk management was largely confined to micro-underwriting of individual credit extensions. As early as the 1960s, work by Ed Altman and others introduced formal quantitative techniques into the analysis of the credit quality of individual firms. Later work drew on:

- actuarial techniques
- the history of credit rating transitions
- implications of option pricing theory in the context of limited liability corporations, and
- reduced form regression analysis and hazard rate analysis of default history against both firm-specific and macro-economic variables.[1]

These techniques introduced a new level of quantitative rigor into what had long been an almost purely judgmental process. Even so, analysis of portfolio characteristics and the impact of diversification was rare. The lack of such analysis had few practical consequences, since there were limited available means for a bank to reshape its credit exposures in any case.

Beginning in the 1990s, instruments arose to lay off and take on credit exposure of varying kinds. This made the application of modern portfolio analysis to bank balance sheet management more than a theoretical curiosity, it made it a practical and competitive necessity.

Today credit risk management faces three broad issues.

- First, growing complexity of structured instruments has not been matched by regulations and incentives to maintain, organize and distribute the massive quantity of detailed data needed to analyze them effectively. In this context, the market fell back on overly simplistic aggregate valuation tools, such as the Gaussian Copula "Model", that have proven to be seriously flawed.
- Second, the application of quantitative micro-analysis of individual obligors has not been

matched by corresponding attention to macroeconomic factors that drive covariability of firms across a diversified credit portfolio. This is an especially serious problem in the context of analyzing major stress scenarios.

- Third, the growing application of quantitative techniques gave rise to a problem of "Two Cultures". There often was, and still is, a palpable lack of understanding and effective communication between traditional judgmental credit analysts and their more quantitatively oriented colleagues. This failure of communication and understanding has hampered the insights of both groups.

How practitioners address these issues will determine the effectiveness of credit risk management in coming years.

I. RETROSPECT

1.1 The Transformation of Credit Risk Management

Up until 50 years ago, traditional credit risk management dominated the way banks thought about the potential failure of obligors to meet their commitments. This approach essentially involved detailed micro-analysis of:

- a company's financial history and current status
- the size and prospective growth of its market
- its management
- its competitors
- barriers to entry into its market such as
  - — tariffs
  - — patents
  - — economies of scale
  - — an established service network
  - — brand recognition
  - — alternate technology, etc.

1.2 The Altman Z-Scores[2]

In the early 1960s, a then young academic named Ed Altman turned his attention to improving the rigor of credit risk analysis. Focusing on accounting statements, he developed a weighted average of five financial ratios that he called a Z-score.[3] The five ratios and the weights were chosen to maximize the discriminatory power of the resulting index in predicting default over the one and two years following the date of the statements.

In effect, Altman brought rigorous statistical techniques to the task of defining a credit quality index. In practice, a Z-score was generally supplemented by more qualitative factors such as those cited above. For nearly 50 years, various manifestations of the Altman Z-score have continued to play an important role in fundamental credit analysis.[4]

1.3 Beyond a Purely Micro Focus

Through much of the 1980s, despite the types of quantitative advances developed by Altman and others, if you asked a banker how his institution controlled its credit risk, the answer tended to be something like, "We only make good loans." The mindset and discipline that this approach involved should not be underestimated. Careful attention to the details on the ground is an essential part of the process of controlling credit losses. What this approach ignores, however, is that the financial strength of some obligors will be affected very differently from that of others in the face of any given economic situation. In effect, a purely micro-underwriting approach ignores the central insight of portfolio theory that diversification often can reduce risk (measured as the volatility of value) without lowering expected return.

To a large extent, this lack of attention to portfolio issues was a consequence of the buy-and-hold model of banking combined with the regional fragmentation of the industry. Banks tended to be captive to the industrial structure of their service areas but there were limited ways to reshape the composition of their credit exposures. In this environment, defining a preferred exposure profile might have been an interesting theoretical exercise but it had little practical value.

1.4 Upheavals Strain the Traditional Bank Business Model

Beginning in the early 1970s, several forces began to undermine this long established model of how banks

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conducted their business. The significant economic volatility of this era, driven in part by two huge spikes in the price of oil in 1973–74 and 1979, put significant stress on the illiquid structure of bank balance sheets. A variety of instruments arose to allow banks to transfer their assets to each other and to non-bank holders and to reshape their exposures by synthetic means. These instruments included collateralized securities based on retail assets such as home mortgages, auto loans and credit card balances. In the commercial lending arena, an active market for trading whole loans developed and was followed by the introduction of Collateralized Loan Obligations (CLOs) backed by portfolios of commercial loans. The early 1990s saw the beginning of single name Credit Default Swaps (CDSs) as well as basket CDS structures that could be customized to meet the hedging needs of a specific end-user very effectively.[5]

These innovations enabled a major shift in the business model of banks from originate-and-hold to originate-and-distribute. Of necessity, it also focused attention on the portfolio dimension of credit risk management. The risk of any collateralized pool depended not just on the average credit quality of the underlying obligations but on how likely they were to experience simultaneous credit weakness. Furthermore, these innovations offered banks the ability to restructure the composition of their credit exposures across regions and industries. Suddenly, application of quantitative modern portfolio concepts to the management of bank balance sheets was not just a theoretical curiosity; it had become a practical and competitive necessity. This gave rise to several additional approaches to estimating credit quality.

1.5 The Actuarial Approach

The actuarial approach to portfolio default estimation was at the core of the CreditRisk+ model introduced by Credit Suisse Financial Products in 1997. This approach treats estimation of the default distribution of a portfolio of credit risky assets as analogous to the mortality distribution of a population of people of different ages and health conditions. The probabilities of default are drawn from historical survival statistics for corporations of various ratings. The method does not reference financial statement data or equity market valuations.

The assumptions behind the model are that the probability of default in any sub-period, say a month, is the same as any other sub-period of equal length. It also assumes that the number of defaults in one period is independent of the number of defaults in any other period. Given these assumptions, the probability distribution of the number of defaults during a given period is well approximated by a Poisson distribution.

It is recognized that defaults are sensitive to the general state of the economy. This can be incorporated into the method by making the mean number of defaults a stochastic variable linked to an indicator of economic conditions. This can be extended further by linking the variability of default rates to multiple background factors tied to specific industries. The mean default rates for specific obligors are then estimated as linear functions of these factors.

One drawback of the actuarial approach is that it only addresses default risk and ignores the impact of rating downgrades. Nevertheless, this is broadly consistent with the traditional historical cost treatment of banking book assets. It also assumes that exposure to each obligor is known and fixed, which requires treating committed but unused credit lines as having known exposure at default.

1.6 Credit Migration Approach

Just as Ed Altman's analysis was a rigorous extension of traditional approaches to credit risk assessment, so the credit migration approach builds on historical data for credit ratings. A transition matrix displays all rating classes in the headers for both the columns and the rows. The elements of this matrix indicate the probability that an obligor starting a period with a rating corresponding to the row will end the period with the rating corresponding to the column. The largest probabilities tend to lie along the diagonal, indicating the high likelihood that a firm's rating will be unchanged during the period.

In its simplest form, this approach makes the aggressive assumption that the probability of a firm migrating to another rating is the same for all firms in a given rating class. For multi-period analysis it is

1250001.indd 3 6/29/2012 5:44:26 PM

possible to introduce momentum factors for one or more periods if the data are available to support this level of detail. In this case, entities that migrated in the previous period or periods are deemed to have different future transition probabilities than those with ratings that have been stable. In addition, it is possible to apply different transition matrices depending on the projected state of the economy.

Extending the transition approach to modeling multiple holdings requires some means of imposing correlations on the migration behavior. The approach implemented by CreditMetrics involves simulating the value of each firm's assets against a grid that maps simulated asset values to corresponding credit ratings. This mapping preserves the migration probabilities of the applicable transition matrix. Historical correlations among each firm's equity value changes are used as proxies for asset correlations and these are imposed on the simulation process. Future cash flows are then discounted in each simulation based on rates appropriate to the credit rating implied for each instrument in that scenario. Repeating this simulation many times produces an estimated distribution of future portfolio values from which a credit value-at-risk estimate can be derived.

1.7 The Merton Model

In 1974, Robert Merton pointed out that the legal structure surrounding a limited liability corporation implies that debt holders have effectively written a put on the assets of the firm to the benefit of the equity holders. The strike price for this put is the book value of the liabilities. If the market value of the unleveraged assets falls below the book value of the liabilities, the equity holders have the option to "put" the assets to the debt holders. This effectively limits the downside loss of the equity holders while leaving them with unlimited upside potential, which is identical to the payoff of an asset owner with a put option.

Unfortunately the market value of the unleveraged assets is not observable. The market value of the equity can be observed, but it combines the value of the excess assets (i.e., total assets less the book value of the liabilities) and the value of the implicit put option on the assets. In addition, however, it is possible to observe the market consensus implied volatility of the value of the equity based on the option market. From these two sources, it is possible to tease out estimates for both the level and the volatility of the value of the corresponding assets. Taken together, a) the empirical distribution for asset values based on history, b) the estimated current level and volatility of asset values and c) the book value of debt provide a basis for estimating an expected default frequency. Furthermore, since the asset values are estimated explicitly, their observed correlations can be calculated directly rather than imputing correlations based on changes in equity values.[6]

The Merton Model approach represents a significant departure from traditional credit analysis techniques. Rather than examining fundamentals directly, the intent is to extract the implication of the combined analysis of the market as it is manifested in a firm's stock price. Initially, traditional credit analysts were almost universally skeptical of attempts to deploy the Merton Model in practice. While that skepticism has softened in recent years, it remains quite common. Nevertheless, most balanced assessments deem the approach to be broadly successful. Proponents argue that the model captures credit deterioration in specific entities much sooner than traditional credit analysis tools. Skeptics counter that market-based assessments such as the Merton Model produce too many predictions of deterioration that fail to materialize.

The biggest shortcoming of the Merton approach is that it is a purely statistical technique based on the history of equity values and equity option prices. Historical default probability estimates have no direct link to specific firm financial characteristics other than the level and maturity of liabilities or to the influence of macroeconomic events. Forward looking simulations are driven by the volatility and correlation assumptions imposed on the stochastic behavior of changes in the market value of assets. It has no means of distinguishing the differential impact of alternative macroeconomic scenarios. This makes it ineffective for scenario evaluation and stress testing, which are increasingly important forms of analysis both to satisfy regulatory demands and for internal assessment of vulnerability to potential extreme events.

1250001.indd 4 6/29/2012 5:44:26 PM

1.8 Beyond the Merton Model

Various analysts have extended the basic Merton Model in ways that are broadly consistent with its initial framework. Most of these continue to rely, however, on implicit estimation from observable bond prices, credit default swap prices, option prices or some combination of these. This leaves them vulnerable to the criticism that they are of limited value for scenario analysis and stress testing. An alternate approach is to derive the full term structure of default probabilities by explicit estimation using a historical default database. This alternate approach was first implemented on a sustained basis by Robert Jarrow and Donald van Deventer in 2002.[7]

The approach used in deriving default probabilities from historical data employs a hazard rate modeling estimation procedure using logistic regression. Estimated default probabilities $P[t]$ are fitted to a historical database with both defaulting and non-defaulting observations and a list of explanatory variables X_i. Chava and Jarrow (2004) note that a logistic regression is the maximum likelihood estimator when trying to predict a dependent variable that is either one (i.e., in the default case) or zero (in the "no default" case). The explicit equation form used is:

$$P[t] = 1/\left[1 + \exp\left(-\alpha - \sum_{i=1}^{n} \beta_i X_i[t]\right)\right].$$

This reduced form approach can employ any variable that improves the quality of default prediction, including Merton default probabilities if they have explanatory power. This means that the reduced form approach can never be worse than the Merton Model because the Merton Model results can always be an input. The explanatory X_i values in this equation also can include the inputs to a traditional Altman Z-score. In this sense, the reduced form/logistic regression approach draws on the preceding work of both Altman and the several variations of the Merton Model. Investigating the contribution of relevant macroeconomic variables to the determination of firm-specific default probabilities is a logical and consistent extension to this basic estimation approach.

Relative to earlier methods, this process produces improved ordinal ranking of companies for grouping into defaulting and non-defaulting categories at various horizons. Adjustment of default probabilities up or down, preserving the ordinal ranking, assures that the default probabilities estimated are consistent with the likelihood of default as revealed by the actual number of failures observed over the historical sample.

Default/bankruptcy predictions are an issue of academic interest. Substantial methodological advancement has been made in recent years. For example, Duffie *et al*. (2007) model defaults using the doubly stochastic Poisson processes with explicit consideration of the censoring effect arising from other exits such as mergers and acquisitions. Duan *et al*. (2012) devise a forward-intensity approach to model defaults and other exits.

Once the best estimates of historical probabilities of default (PDs) are derived using all empirically useful micro and macro factors, a straightforward step is to estimate a "reduced-reduced form" equation to explain as much of the historical movement in the PDs as possible based on macroeconomic factors alone. The difference between the resulting predicted values and the historical PD estimates can be viewed as company-specific idiosyncratic risk that is uncorrelated across companies in the universe under consideration.

These reduced-reduced form PD equations are ideal for evaluating the expected impact of hypothetical stress scenarios. They also can be used as the basis for Monte Carlo simulations conditional on a given macro-economic scenario. In this case, the idiosyncratic components can be simulated on an uncorrelated basis, since the macro-economic and industry factors have been accounted for in the structure and parameters of the reduced-reduced form relationship.

II. PROSPECT

2.1 Structured Securities: The Failure of Top-Down Pricing

In some extreme cases, quantitative credit analysis has become almost exclusively macro oriented and

1250001.indd 5 6/29/2012 5:44:26 PM

effectively detached from the micro details of the underlying obligations and their obligors. The most serious example of this is the use of Gaussian Copulas to evaluate different tranches of Collateralized Debt Obligations (CDOs). These instruments often have tiered loss tranches designed to attract a variety of investors with a wide range of risk/reward profiles into the debt markets.

Everyone understands that default correlation is central to the distribution of total credit losses in a CDO. Nevertheless the casual, even simplistic manner in which correlation has been used in quoting prices for these instruments should give one pause. Rather than building on the characteristics of the actual underlying instruments in a portfolio, each tranche is priced on the basis of *one* pair-wise correlation across *all* names. Not only that, the single common correlation used for all names is different for different tranches, leading to what is known as the correlation smile. In effect, no single consistent stochastic structure is ever able to explain the price for all components of this type of instrument. Once fully understood, this is an anomaly of breathtaking proportions.

In truth, the Gaussian Copula "Model" is not a model at all. It was simply a handy way for traders to communicate with each other. The model has only a very tenuous link to the characteristics of the underlying collateral through the average default rate. The covariability is treated only by implication from the prices of each traunch and even here the treatment is internally inconsistent.

2.2 Structured Securities: The Transition to Bottom-Up Pricing

Transitioning to a bottom-up approach to pricing structured securities is both an analytical and an infrastructure challenge. At the heart of the problem is that the complexity of credit instruments has increased dramatically in the past 25 years. This complexity has advanced on two fronts. First collateralized securities have been created based on an ever wider range of underlying obligations. What began as a way to package large commercial obligations or home mortgages subject to strict and inflexible underwriting standards has expanded to include auto loans, revolving credit card debt, trade receivables and even such things as future movie royalties. What has lagged far behind is an infrastructure to provide ready access to all relevant risk related data on the underlying obligations. The second source of complexity is the wide variety of ways in which customized payment waterfalls are constructed. What is needed is an analytical tool to access the details of the payment waterfall and a means to assess how any given structure will allocate the available cash under different stress scenarios.

In large measure the failure of markets to address these two problems is not surprising. The dual forms of complexity combined with the absence of adequate data and the associated analytical tools to evaluate their implications have fostered ever greater opacity in credit markets. This inevitably works to the advantage of large sell-side firms. In a crisis, these firms themselves can fall victim to this opacity (consider Bear Sterns, Lehman Brothers, RBS and others). Nevertheless, on a day-in and day-out basis, opacity clearly supports wider bid-offer spreads that serve to enrich those who make markets in these instruments. It is hardly surprising that sell-side firms oppose reforms to bring greater transparency to these markets with all the political pressure that their financial clout can command.

What is surprising is how passive buy-side firms have been in accepting this situation as an unavoidable state of nature. It can be argued that until recently the cost and availability of computer information storage, processing power and communication capacity presented significant obstacles to addressing this problem. Today those obstacles have largely disappeared. A system where the underlying details of every individual mortgage in a MBS (such as up-to-date information concerning payment status, geographically related comparables, original and current loan-to-value ratios and much more) along with the cash flow structure of the security and the implications of pre-existing defaults or repayments, could be maintained in a coherent database available to market participants. The main obstacle to this is resistance to divulging information that is deemed to convey competitive advantage. Technology can create and maintain greater transparency in these markets if the

1250001.indd 6 6/29/2012 5:44:26 PM

buy-side, regulators and the general public can muster the collective will to demand it.

2.3 Market-Driven Transparency

How could such a facility become a standard feature of the markets for complex financial products? As Adam Smith would have said, we will not accomplish this by appealing to "the benevolence of the butcher, the brewer" or the investment banking executive. The dramatic improvement in transparency that technology now makes possible will only be fully realized and effectively maintained through appeals to self-interest. In addition to regulatory pressure, establishing such a system will require several things. First it will require a well heeled insurgent organization with little or no stake in the current market arrangements to underwrite the technical development of such a system.

The Credit Research Initiative developed by Risk Management Institute at NUS in 2009 is providing such a facility in the domain of corporate credit risk. More specifically, through an easy-to-use web portal, the PDs for nearly 50,000 firms are available for users who can give evidence of their professional qualifications to ensure that they will not misuse the data. General users without global access are restricted to a list of 2,200 firms. Full transparency is obtained by documenting the methodology and operational implementation in a technical report that is accessible to all users.

Second it will require participation commitments from a core group of buy-side firms that would stand to benefit from the greater transparency, lower risk and sharper pricing that such a system would create. Finally, it will require commitment from some aspiring second-tier sell-side firms that would stand to benefit from a first mover advantage by being an early participant in such a transformative arrangement and the big increases in trading volume it would create.

Essential to the success of such an arrangement will be establishing sufficient trading volume and associated liquidity to assure investors that they can transact in reasonable volume without significant impact on prevailing prices. Marketcore,[8] an intellectual property company, has designed a patented business method to achieve this goal. It is centered on provision of time-limited transaction credits to liquidity providers. These credits provide either discounts on future trades or privileged access to the uniquely valuable detailed data such a system makes available. In essence, the business method leverages the most valuable commodity such a system creates, namely the consistently organized detailed data on the complex securities being traded, to solve the key challenge that any new trading system faces, namely building reliable liquidity.

The stars are well aligned to support such a development. One indication of this is that the first such transformation is actually in initial operation. LexisNexis has collaborated with the Council of Insurance Agents and Brokers (CIAB) and Marketcore to create the LexisNexis Insurance Exchange.[9] It is initially focused on property and casualty policies but it has plans to expand into life and health as well as reinsurance. Since a similar mechanism would be equally applicable to various heterogeneous credit and derivative instruments, this might just be the beginning of a much broader market transformation.

If this transformation materializes, it will result in more robust and resilient credit markets. Such a structure would allow a wide variety of analysts to track and evaluate these securities based on reliable empirical data rather than on marketing hype or on complex top-down analytic techniques that are largely out of touch with the actual underlying collateral. In the end, such a structure would provide many opportunities even for those sell-side firms that will resist it the most. A more transparent market built on access to reliable and up-to-date detailed data will generate demand for new and innovative hedging instruments that these firms are so well equipped to provide. Given the broad social benefits that flow from more efficient allocation of savings into real investments with the best return, we all should work to realize this vision.

2.4 Portfolio Dynamics: From Simple Correlations to Structural Analysis

Covariability is also an issue for aggregate bank portfolio analysis. Following the traditional Markowitz model, most statistical approaches to credit risk assessment rely on historical correlations to evaluate the implications of covariation in credit quality across the portfolio through time. The problem with this

1250001.indd 7 6/29/2012 5:44:26 PM

approach is that it only captures the average pattern of covariation over the available sample period.

Movements in credit quality are typically driven by a combination of macro-economic events and idiosyncratic factors specific to each company. In this context, most of the covariation across individual companies is explained by common sensitivities to macro-economic factors. A simple correlation approach only reflects the impact of the average historical business cycle. The problem is that different business cycles are driven by different forces and any one past cycle or hypothetical future scenario may diverge considerably from the historical average. An approach that simulates portfolio behavior using only past average covariation is bound to miss important aspects of any specific potential scenario. It is for this reason that I believe greater use of structural linkages, albeit in reduced form such as in the approach by Jarrow and Chava (2004), Duffie *et al*. (2007) or Duan *et al*. (2012), is the best available analytical method in an increasingly uncertain world.

2.5 Behavioral Obstacles and the Danger of Two Cultures

As this paper illustrates, credit risk analysis has become increasingly quantitative and technical over the past several decades. Much of this analysis has been viewed with varying degrees of skepticism by traditional credit analysts. In a very real sense this mirrors a cultural problem that C.P. Snow described in his 1959 essay entitled *The Two Cultures and the Scientific Revolution*. In it Snow highlighted the often willful lack of communication between scientists and literary intellectuals.[10] In all too many cases, Snow argued, formal training compounded inherently different mindsets to produce a nearly complete lack of understanding and communication across these two cultures. Scientists, he found, often had little interest in or exposure to imaginative literature. On the other side, literary intellectuals often treated their realm as the whole of culture, blithely oblivious to the scientific edifice of the physical world as "in its intellectual depth, complexity and articulation, the most beautiful and wonderful collective work of the mind of man".

A similar problem afflicts the practice of modern finance, namely the split between "quants" and the larger community of traditional finance managers. Quantitative techniques and statistical risk management are little more than opaque black boxes for all too many general financial executives. What is more, those who do understand the technical details often have limited insight into broader structural and behavioral issues. They also have little incentive to make their work more transparent to outsiders since this would undermine the "mystique" that surrounds their skill set.

In some cases, a lack of technical insight has little or no serious consequences. After all, few of us can understand the technical mechanics of a modern automobile but that does not inhibit our ability to drive. In the case of financial management, however, the impact of Two Cultures can be serious indeed. This is primarily because running a financial institution demands a constant series of large and small decisions under uncertainty. Such decisions can never be effective if they are made mechanically. Effective decisions must reflect experience and judgment *conditioned by the available empirical evidence*. As finance has become ever more complex and quantitative, the communications gap between its Two Cultures has become ever more consequential. Most senior bank managers are unable to weigh the subtle details of modern quantitative finance and few state-of-the-art quants are well equipped to assist them (even if they were motivated to do so).

The weakness of the Gaussian Copula model discussed previously is a case where the existence of Two Cultures was an obstacle to effective risk management. If more general business executives had fully grasped the utter inadequacy of the analytical framework on which this huge market was based, it is possible that more firms would have acted sooner to pull back from the brink as the sub-prime sector of this market approached the point of collapse.

Unfortunately I have no magic answer to the Two Cultures problem. The number of people with the background to feel genuinely comfortable in both cultures will continue to be limited. Recognizing their contribution as a bridge to facilitate communication across the organization and to raise the level of insight on both

sides of the cultural divide is a step in the right direction. Offering opportunities where representatives from both cultures can interact on substantive issues, such as senior policy committees, will also help. Beyond this, just raising awareness of the potential dangers from miscommunication and lack of insight across the groups can be helpful when important decisions depend on considerations from both perspectives.

III. CONCLUSION

Credit risk management has been transformed beyond recognition over the past 50 years. That transformation has accelerated over the past 20 years with the introduction of capital market instruments to transform and transfer credit exposure among market participants. Competitive success will require that firms develop effective working relationships across traditional qualitative credit analysts and their newer more quantitative associates. It will also require greater attention to portfolio dynamics and the impact of macro-economic factors to gain maximum advantage from the instruments that allow firms to reshape the composition of their credit risk exposure. Finally, collective attention is essential from the financial industry and regulatory institutions to establish regulations and incentives to create, organize, maintain and distribute the ever growing mountain of detailed data needed for effective bottom-up valuation and risk analysis of the increasingly varied and complex instruments available in the market. Lacking the raw material for sound analysis, there is little institutions can do but wait for the next crisis driven by irrational enthusiasm that goes unchallenged by empirically grounded insights.

NOTES

[1] Other nonlinear analytical tools, such as support vector machine and neural network have also been applied to default analysis. For a more comprehensive account of statistical tools for default analysis, readers are referred to Duan and Shrestha (2011).

[2] This and the following five sections draw heavily on Rowe and Day (2007a).

[3] Altman's original ratio was tailored to public industrial companies and involved the following five financial ratios: (A) EBIT/Total Assets, (B) Net Sales/Total Assets, (C) Market Value of Equity/Total Liabilities, (D) Working Capital/Total Assets and (E) Retained Earnings/Total Assets. The Z-score was defined as: Z-score = $3.3 \times A + 0.999 \times B + 0.6 \times C + 1.2 \times D + 1.4 \times E$.

[4] Indeed Dr. Altman himself, now just past 70, continues his research and remains a widely quoted expert on credit risk issues.

[5] For further background on the history of these developments, see Rowe and Day (2007b).

[6] The estimation method described here is a volatility restriction method. A comprehensive discussion on the pros and cons of this and other estimation methods are available in Ericsson and Reneby (2005) and Duan and Wang (2012).

[7] Please note that I am a Senior Advisor to Kamakura, the main commercial provider of this type of analysis. My association with the firm has only strengthened my conviction that this approach is the most effective available means of deriving an empirically based translation of macro events to their micro credit implications.

[8] See http://www.marketcore.com/index.php. In the interest of full disclosure, I should note that I am a Senior Advisor to Marketcore as well as Kamakura.

[9] See http://www.businessinsurance.com/article/20120101/NEWS04/301019988 and http://blogs.lexisnexis.com/insuranceexchange/2012/02/10/getting-left-behind-is-closer-than-you-think/

[10] Snow was a trained scientist who also wrote imaginative literature. As such, he was uniquely qualified to assess the problem of The Two Cultures.

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