

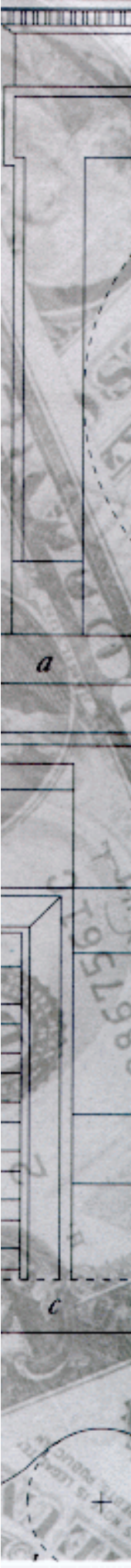
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*The New Basel Capital Accord and
Questions for Research*

by
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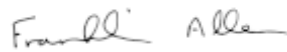


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The New Basel Capital Accord and Questions for Research¹

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Abstract: The New Basel Accord for bank capital regulation is designed to better align regulatory capital to the underlying risks by encouraging better and more systematic risk management practices, especially in the area of credit risk. We provide an overview of the objectives, analytical foundations and main features of the Accord and then open the door to some research questions provoked by the Accord. We see these questions falling into three groups: what is the impact of the proposal on the global banking system through possible changes in bank behavior; a set of issues around risk analytics such as model validation, correlations and portfolio aggregation, operational risk metrics and relevant summary statistics of a bank's risk profile; issues brought about by Pillar 2 (supervisory review) and Pillar 3 (public disclosure).

Keywords: Bank capital regulation, risk management, credit risk, operational risk

JEL Codes: G21, G28

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1. Introduction

There are broadly two sets of reasons often given for capital regulation in financial institutions broadly and banks in particular. One is the protection of consumers from exploitation by opaque and better-informed financial institutions; for banking the objective would be depositor protection. The second is systemic risk.³ Banks are often thought to be a source of systemic risk because of their central role in the payments system and in the allocation of financial resources,⁴ combined with the fragility of their financial structure.⁵ Banks are highly leveraged with relatively short-term liabilities, typically in the form of deposits, and relatively illiquid assets, usually loans to firms or households. In that sense banks are said to be “special” and hence subject to special regulatory oversight.

There is a tight linkage between deposit insurance and capital regulation. Deposit insurance is designed to overcome the asymmetry of information in the banking system (Diamond and Dybvig (1983), Dewatripont and Tirole (1994)). The bank knows more about the riskiness of its activities than do its depositors. A depositor, therefore, is unable to tell a good bank from a bad one. Because banks are highly leveraged institutions, depositors have a strong incentive to show up at the bank first to withdraw their funds in case they doubt the financial health of a particular bank. Those at the end of the line may get nothing. In short,

³ Not all observers agree that systemic risk should be an important objective of bank capital regulation. See, for example, Benston and Kaufman (1995).

⁴ In many countries banks control 70% or more of the assets in the financial system. In the U.S., however, the bank share of total assets has fallen to little more than 20% (Basel Committee on Banking Supervision 1996, p. 126).

⁵ For an interesting cross-sectoral comparison, see Joint Forum (2001).

deposit insurance is designed to prevent depositors from overreacting to bad news about banks.⁶

The creation of such a safety net comes at a cost, namely moral hazard. Depositors no longer have an incentive to monitor (or pay to monitor) banks since their deposits are guaranteed up to the coverage limit (currently \$100,000 per individual per institution in the U.S.). Banks have an attendant incentive to increase risk. Hence the name of the game in designing a safety net has been to balance the need to prevent bank panics (and other social costs to bank failure such as credit crunches) with the moral hazard brought on by the very presence of the safety net. The regulation of bank capital is often justified to achieve this balance.⁷

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)). Bank regulators have long regarded the prevention of systemic risk as the fundamental rationale for imposing capital requirements on banks. The assumption is that shareholders will not take account of the social costs of systemic risk in their capital decisions and so will tend to hold less capital than if these spillover costs were considered.

⁶ Bank runs and panics were quite real and prevalent in the US in the 19th and early 20th centuries. In the years preceding the creation of the FDIC (i.e. 1930-33), the number of bank failures averaged 2000 per year (Mishkin (1997)).

⁷ Santos (2001), in a survey of the bank capital regulation, points out the necessity of jointly considering the problems of deposit insurance pricing, lender of last resort and bank capital standards and regulation. “In general, the optimal regulation encompasses a menu of regulatory instruments, designed to extract information from banks and minimize the cost of ‘bribing’ the lower quality banks to mimic the higher quality ones.” (Santos (2001) p. 59). In short, while the information asymmetry inherent in banking is a real issue, deposit insurance may not be the only solution, and if deposit insurance is chosen, its design matters in determining banking stability and efficiency.

Capital requirements are intended to mitigate the risks of adverse selection by ensuring that the financial firm has at least some minimal level of resources to honor its commitments to its customers. Capital requirements are intended to mitigate moral hazard by ensuring that the owners of a financial institution have a stake in ensuring that the firm does not engage in fraud and conforms to conduct of business rules, if only to avoid fines or loss of equity value. To be effective in this role, capital requirements must be sensitive to the risks to which an institution is exposed.

Formal and systematic bank capital regulation is relatively new. The 1988 Basel Capital Accord, or Basel I (Basel Committee on Banking Supervision (BCBS) (1988)), which set minimum capital standards for internationally active banks, was really the first international accord of its kind. It succeeded at raising capital levels at a time when they were quite low. Aside from defining what types of capital were eligible, Basel I set a capital ratio at 8% of risk-adjusted assets. It was the risk-adjustment of the assets which became the focus of concern and current regulatory reform resulting in the New Basel Capital Accord or Basel II (BCBS (2001)).

The New Basel Accord for bank capital regulation is designed to better align regulatory capital to the underlying risks by encouraging more and better systematic risk management practices, especially in the area of credit risk. Compliance with an even more risk sensitive capital ratio is only one of three pillars under the Accord. Revisions to the New Accord also introduce banks' internal assessments (subject to supervisory review – Pillar 2) of capital adequacy and market discipline (through enhanced transparency – Pillar 3) as key components of prudential regulation. It may therefore come as no surprise that underlying the Accord is some formal economic modeling. Both the models and their implication for

implementation of the Accord open the door to many research questions. We see these questions falling into three groups: what is the impact of the proposal on the global banking system through possible changes in bank behavior; a set of issues around risk analytics; issues brought about by Pillar 2 (supervisory review) and Pillar 3 (public disclosure).

The rest of the paper will proceed as follows. In Section 2 we expand on some of the problems that Basel I brought with it; Section 3 will provide an overview of the main objectives of Basel II, details of which are provided in Section 4. In Section 5 we will cover the questions the new accord raises for the research community. Section 6 provides some final comments.

2. Problems with Basel I

To understand and appreciate the basic goals of Basel II and the strategy for achieving these goals, it is important to understand the shortcomings of the current Basel Capital Accord (Basel I). Under the current Accord, capital requirements are only moderately related to a bank's risk taking. The requirement on a credit exposure is the same whether the borrower's credit rating is triple-A or triple-C. Moreover, the requirement often hinges on the exposure's specific legal form. For example, an on-balance sheet loan generally faces a higher capital requirement than an off-balance sheet exposure to the same borrower, even though financial engineering can make such distinctions irrelevant from a risk perspective.

This lack of risk sensitivity under the current Accord distorts economic decision making. Banks are encouraged to structure transactions to minimize regulatory requirements or, in some cases, to undertake transactions whose main purpose is to reduce capital requirements with no commensurate reduction in actual risk taking. As an example, no

capital charge is assigned to loans or loan commitments with a maturity of less than one year. Perhaps not surprisingly, 364-day facilities have risen in popularity. The corollary to this problem is that the current system fails to recognize many techniques for actually mitigating banking risks. A closely related concern is that the current Accord is static and not easily adaptable to new banking activities and risk management techniques. Lastly, some banks may have been reluctant to invest in better risk management systems because they are costly and would not provide tangible regulatory capital benefits.

The lack of risk sensitivity also impedes effective supervision. Although both banks and supervisors have been working to improve their assessments of capital adequacy, these assessments continue to center on comparisons of actual capital levels against the regulatory minimums. Bank examiners continue to focus on these ratios in part because they are part of the legal basis for taking supervisory actions. Reflecting supervisors' emphasis on regulatory capital ratios, financial markets and rating agencies tend focus on them as well. Consequently, in some cases supervisors and even the banks themselves may have limited information about a bank's overall risk and capital adequacy. In this setting, it is difficult to ensure that banks and supervisors will respond to emerging problems in a timely manner.

3. Objectives of the New Basel Accord

Broadly speaking, the objectives of Basel II are to encourage better and more systematic risk management practices, especially in the area of credit risk, and to provide improved measures of capital adequacy for the benefit of supervisors and the marketplace more generally. At the outset of the process of developing the new Accord, the Basel Committee developed the so-called three pillars approach to capital adequacy involving (1)

minimum capital requirements, (2) supervisory review of internal bank assessments of capital relative to risk, and (3) increased public disclosure of risk and capital information sufficient to provide meaningful market discipline. Although the Committee's proposals have evolved considerably over the past several years, these fundamental objectives and the three-pillar approach have held constant.

It is hardly necessary to emphasize the importance of banks and banking systems to financial and economic stability.⁸ The ability of a sound and well-capitalized banking system to help cushion an economy from unforeseen shocks is well known, as are the negative consequences of a banking system that itself becomes a source of weakness and instability. A critical potential weakness of financial markets is that risks are in many cases under-estimated and not fully recognized until too late, with a concomitant potential for excessive consequences once they have been fully realized. This is why the Basel Committee's efforts to promote greater recognition of risks and more systematic attention to them are vitally important.

The essence of Basel II is a focus on risk differentiation and the need for enhanced approaches to assessing credit risk. Some critics have argued that it is preferable to downplay differences in risk, and indeed forbearance can sometimes appear the most expedient strategy. But experience has also shown that this will not work as an overall approach because ignoring risks inevitably leads to larger problems down the road. Thus, one of the key messages of Basel II is that bankers, supervisors, and other market participants must become better attuned to risk and better able to act on those risk assessments at the appropriate time. Bank supervisors must get better at addressing issues pre-emptively rather than in crisis mode.

Significant attention to risk management is one of the primary mechanisms available to help banks and supervisors do that.

Basel II seeks to provide incentives for greater awareness of differences in risk through more risk-sensitive minimum capital requirements. The Pillar 1 capital requirements will, by necessity, be imperfect measures of risk as any rules-based framework will be. The objective of the proposals is to increase the emphasis on assessments of credit and operational risk throughout financial institutions and across markets.

Perhaps even more important in the long run is the second pillar of the new Accord. Pillar 2 requires banks to systematically assess risk relative to capital within their organization. The review of these internal assessments by supervisors should provide discipline on bank management to take the process seriously and will help supervisors to continually enhance their understanding of risk at the institutions. The third pillar of Basel II provides another set of necessary checks and balances by seeking to promote market discipline through enhanced transparency. Greater disclosure of key elements of risk and capital will provide important information to counterparties and investors who need such information to have an informed view of a bank's profile.

4. Key Elements of the Package

While the way minimum regulatory capital requirements are computed has changed substantially, what actually counts towards capital has not; the numerator in the capital-asset ratio remains unchanged.⁹ The new Accord outlines two new approaches to assessing credit

⁸ For a broad cross-country study analyzing the real economic impact of banking crises, see Caprio and Klingebiel (1996).

⁹ See Board of Governors of the Federal Reserve System (2002) for review of eligible capital.

risk and for the first time specifies a capital charge for operational risk. In this section we will provide details on both, including a description of the calibration effort that the Basel Committee has undertaken with participants in industry.¹⁰

4.1. Pillar 1: Credit Risk

In order to allow for evolution of credit risk management methods and practices the New Accord introduces a range of approaches for assessing credit risk: a standardized and an internal ratings-based (IRB) approach, the latter having two versions. The standardized approach incorporates modest changes in risk sensitivities to improve risk sensitivities through readily observable risk measures such as external credit ratings. This simple rules-based approach is designed to address some of the most blatant shortcomings of the current Accord. Compared to the current Accord, the IRB approach is fundamentally different in concept, design, and implementation. Consistent with the Basel Committee's objectives, it is intended to produce a capital requirement more closely linked to each bank's actual credit risks – a lower-quality portfolio will face a higher capital charge, a higher-quality portfolio a lower capital charge. Such an approach is essential to creating the correct incentives for both banks and supervisors.

The IRB approach is based on four key parameters used to estimate credit risks:¹¹

1. *PD* The probability of default of a borrower over a one-year horizon
2. *LGD* The loss given default (or 1 minus recovery) as a percentage of exposure at default
3. *EAD* Exposure at default (an amount, not a percentage)
4. *M* Maturity

¹⁰ See Basel Committee on Banking Supervision (2002) for detailed descriptions of each element of the minimum capital requirements.

¹¹ Section III.B, § 23 – 30, of Basel Committee on Banking Supervision (2001a)

For a given maturity, these parameters are used to estimate two types of expected loss (*EL*).
Expected loss as an amount:

$$EL = PD \times LGD \times EAD$$

and expected loss as a *percentage* of exposure at default:

$$EL\% = PD \times LGD$$

There are two variants of IRB available to banks, the foundation approach and the advanced approach.¹² They differ principally in how the four parameters can be measured and determined internally, but an essential feature of both approaches is their use of the bank's own internal information on an asset's credit risk. For the foundation approach only *PD* may be assigned internally, subject to supervisory review (Pillar 2). *LGD* is fixed and based on supervisory values. For example, 45% for senior unsecured claims and 75% for subordinated claims. *EAD* is also based on supervisory values in cases where the measurement is not clear. For instance, *EAD* is 75% for irrevocable undrawn commitments. Finally, a single average maturity of three years is assumed for the portfolio. In the advanced approach all four parameters are determined by the bank and are subject to supervisory review.

The IRB at heart provides a continuous mapping from the basic set of four input parameters (*PD*, *LGD*, *EAD* and *M*), plus some other observables such as borrower type, to a minimum capital requirement. This mapping is based on the same analytical framework as most credit portfolio models.¹³ Gordy (2002) demonstrates that such a risk-bucketing approach, i.e. capital requirements which only depend on the characteristics of an individual exposure, is consistent with an asymptotic single risk factor credit portfolio model, itself based on the Merton (1974) options-based model of firm default.

¹² For qualification conditions, please see Basel Committee on Banking Supervision (2001a).

Taking corporate exposures as an example, risk-weighted assets (RWA) is computed as a function of the basic set of four input parameters: $RWA = K(PD, LGD, M) \times 12.5 \times EAD$, where 12.5 is just the reciprocal of 8% (the overall level of minimum capital as a percentage of RWA).¹⁴

$$(1) \quad K = LGD \times \Phi \left[(1 - \rho)^{-0.5} \times \Phi^{-1}(PD) + \left(\frac{\rho}{1 - \rho} \right)^{0.5} \times \Phi^{-1}(0.999) \right] \\ \times \left(\frac{1}{1 - 1.5 \times b} \right) \times (1 + (M - 2.5) \times b)$$

$$\rho = 0.12 \times \lambda + 0.24 \times (1 - \lambda)$$

$$\lambda = \frac{1 - e^{(-50 \times PD)}}{1 - e^{(-50)}}$$

$$b = (0.08451 - 0.05898 \times \ln(PD))^2$$

where $\Phi(\cdot)$ is the standard normal cumulative density function, ρ is a weighted correlation parameter with the weight λ being determined by the PD , and b is a maturity adjustment. Note that these capital calculations are done at the exposure, not portfolio, level. Total portfolio capital is then simply the sum of all exposure-level capital charges, with an implied correlation level ρ which is effectively a weighted average of 12% and 24%.

In Figure 1 below we graph risk weights as a function of PD for three different levels of LGD and a fixed maturity (M) of 3 years. It is clear that the capital curve steepens quickly for low (annual) probabilities of default and then becomes flatter out past about $PD=2\%$.

¹³ See also Section 5.2.4 below.

¹⁴ Basel Committee on Banking Supervision (2003) and Saunders and Allen (2002).

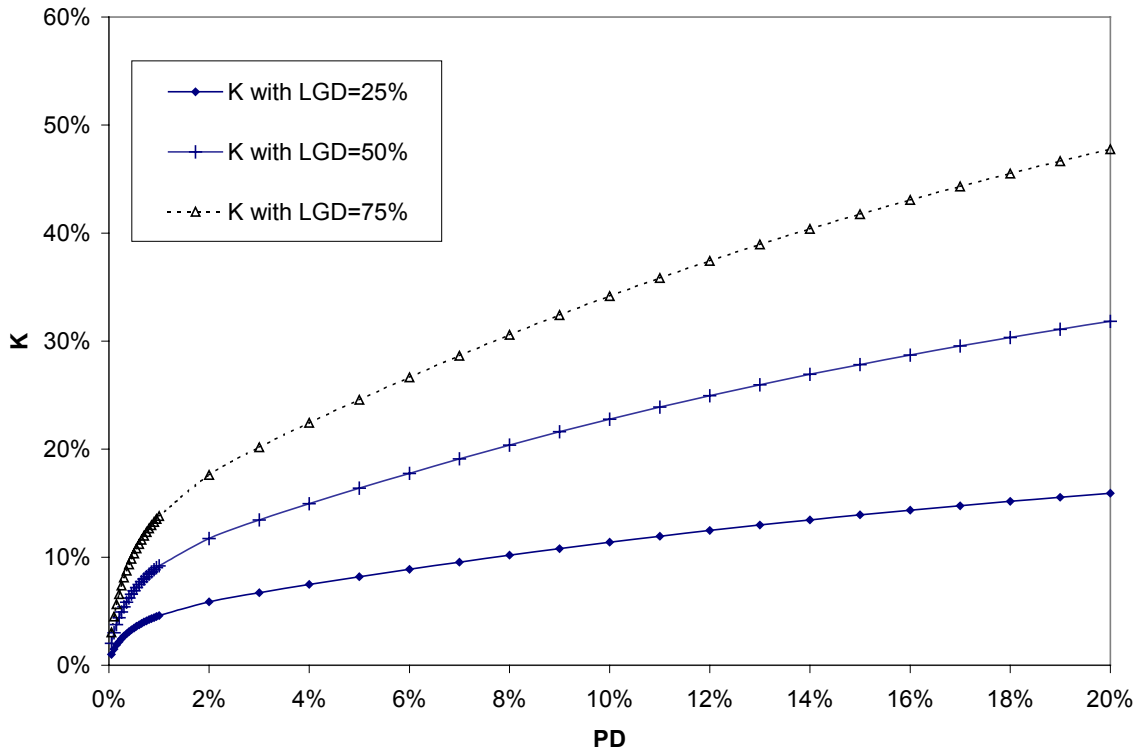


Figure 1: C&I Risk Weight Function

A critical issue with respect to the IRB approach is the reliability of the credit risk parameters supplied by banks, upon which the capital charges are based – specifically the estimated *PDs*, *LGDs*, and *EADs* described above. If these estimates prove unreliable, the IRB approach would provide little, if any, improvement in risk sensitivity over the current Accord. Thus, it is essential that prior to IRB implementation supervisors ensure that a bank’s internal processes for determining internal risk ratings, *PDs*, *LGDs*, and *EADs* are credible and robust. To support this objective, Basel II will require that banks comply with a set of minimum operational requirements in each of these areas. These standards are based on best practices across the banking industry.

As with all aspects of the Basel II framework, these standards have benefited from extensive industry consultations. By design, the Basel Committee has set the bar high in

order to raise the quality of risk management within the banking industry. Although sound practice standards are a critical element, they may have little consequence unless supervisors have the ability to validate and enforce them. In an effort to promote consistency, the Basel Committee has established a forum for supervisors to exchange experiences and ideas regarding IRB implementation.

4.2. Pillars 2 and 3: Supervisory review and public disclosure

Pillar 2 promotes the supervisory review process and is regarded as an essential element of the new Accord. Pillar 2 encourages banks to develop internal economic capital assessments appropriate to their own risk profiles for identifying, measuring, and controlling risks. The emphasis on internal assessments of capital adequacy recognizes that any rules-based approach will inevitably lag behind changing risk profiles of complex banking organizations. The banks' internal assessments of should give explicit recognition to the quality of the risk management and control process and to risks not fully addressed in Pillar 1.

Importantly, Pillar 2 provides a basis for supervisory intervention to prevent unwarranted declines in a bank's capital. The Basel Committee has articulated four principles consistent with these objectives: (1) Each bank should assess its internal capital adequacy in light of its risk profile, (2) Supervisors should review internal assessments, (3) Banks should hold capital above regulatory minimums, and (4) Supervisors should intervene at an early stage.

Much of the focus has been on the third of these principles, with the recognition that the capital buffer should reflect risks that either are not fully captured (e.g. concentration risk) or not taken into account (e.g. interest rate risk, business risk) in Pillar 1. Additionally, the capital buffer should also reflect factors external to the bank (e.g. business cycle effects).

Pillar 3 represents the Basel Committee's efforts to promote market discipline through enhanced transparency and is integral to the success of the New Basel Accord. Pillar 3 is intended to improve disclosures of banks across markets. In particular, Pillar 3 will provide enhanced public disclosures of capital adequacy and risk information. It includes disclosures related to capital and capital adequacy, including the components of the capital structure and regulatory capital ratios, and to risk exposures, including credit, market, interest rate, and operational risks.

The Pillar 3 framework has undergone a number of substantive changes since first proposed. The Committee has maintained throughout the Accord revision process that the disclosures should be mandatory for all banks given the increased reliance on internal assessments of risks. The Committee has also sought to ensure that the disclosures are provided on a timely basis. Finally, the Committee has tried to strike a balance and ensure that the disclosures are meaningful and sufficiently detailed to allow for comparisons across institutions and over time while not becoming burdensome or prescriptive.

4.3. Calibration Effort

The Basel Committee has invested considerable resources attempting to calibrate the IRB risk weight functions. This process has involved constructing supervisory credit risk models for retail and non-retail loan portfolios. The calibration is based upon a credit value at risk (VaR) approach. Under this framework, risk weights are implicitly calibrated so that with a specified minimum probability (the target solvency probability) capital will cover total credit losses. Implicitly or explicitly, the calibration of risk weights involves (1) estimating the volatility or uncertainty in portfolio credit losses over a time horizon taken to be one year,

and (2) given this estimated volatility, determining the level of capital needed to achieve possible target solvency probabilities.

The Basel Committee balanced two broad empirical approaches – one direct and another survey-based – for calibrating IRB risk weights. The Committee looked to survey data from banks and trade groups. This approach uses the economic capital requirements from banks’ internal economic capital systems, thus building upon research already conducted within the private sector. The Committee collected information on banks’ internal economic capital allocations. For each institution these data were used to estimate the implied risk weights attributed by each bank to loans having particular *PD*, *LGD* and maturity.

The Committee also looked to direct or model-based calibration of risk weights to support the survey evidence. This method involved using formal credit risk models to estimate the required capital associated with an individual loan within a large, well-diversified portfolio. Key assumptions, such as correlation parameters, reflected a range of values based on industry practice and independent research conducted with borrower default data from multiple countries. These credit risk modeling exercises produced results comparable to those obtained from the survey evidence.

The development of appropriate risk weight functions and their specific parameters, i.e. the continuous mapping given by (1) in Section 4.1 from the four key risk inputs (*PD*, *LGD*, *EAD*, and *M*) to a minimum capital requirement, is indeed a challenge. In part, these difficulties reflect the limited historical data with which to estimate key credit risk parameters. In addition to these empirical issues, the Committee has also faced a number of fundamental policy tradeoffs. The Basel Committee has a stated objective of ensuring that the capital within the banking system does not either fall or rise significantly with the introduction of the

new Accord. The Committee also sought to address the concern that the introduction of a risk-sensitive capital requirement would be excessively volatile or pro-cyclical. The Committee conducted a number of exercises including a series Quantitative Impact Studies in an effort to address these issues.

4.4. Operational Risk: 3 Flavors

Throughout the Accord revision process, the Basel Committee maintained that there must be an explicit capital charge for operational risk, and that this charge should be risk sensitive. Operational risk is defined as “the risk of direct or indirect loss resulting from inadequate or failed internal processes, people and systems or from external events” (Basel Committee on Banking Supervision (2001), §547). Both the unbundling of the minimum capital requirement into risk sensitive measures of credit and market risk, and the importance of operational risk warranted an explicit capital charge for operational risk. In contrast to credit and market risk, the measurement of operational risk is at an early stage of development with a range, albeit narrowing range, of industry practices. Developing a capital charge for operational risk is challenging both because of a lack of agreed methodology, and because of limited historical loss data.

In response to these challenges, the Basel Committee developed three approaches for measuring operational risk capital requirements. The Basic Indicator approach provides a simple way to determine a capital requirement, based on a percentage of gross income. The Standardized approach assigns a capital charge for each of eight business lines based upon a fixed relation between average industry allocated economic capital and gross income for each business line. Finally, through the Advanced Measurement approach (AMA) the Committee sought to provide flexibility for banks to use their own internal measurement approaches

subject to meeting rigorous qualitative and quantitative standards. One of the key objectives of the AMA is to provide incentives for banks to develop improved measures of operational risk and to encourage operational loss data collection efforts to use as a basis for calibrating the regulatory capital requirements. This is spelled out in BCBS (2002).

5. Questions for Research on Three Fronts

In designing the specifics of the New Basel Accord, regulators made use of advances in the academic literature, particularly in the area of risk management. In turn, the regulatory proposals have become fertile ground for more research. We see these research questions falling into three groups: what is the impact of the proposal on the global banking system through possible changes in bank behavior; a set of issues around risk analytics; issues brought about by Pillar 2 (supervisory review) and Pillar 3 (public disclosure).

5.1. Impact of Proposal on Banking System and Bank Behavior

A stated goal of the New Basel Accord is to keep the overall level of capital in the global banking system from changing significantly, assuming the same degree of risk. Obviously that does not mean that the capital levels of each bank will remain unchanged. The calibration effort discussed in Section 4.3 described how the Basel Committee has gone about ascertaining the impact of the New Accord on the banking system. These calibrations are conducted under *ceteris paribus* assumptions; it is unclear how bank behavior might change once the new Accord is in place. This raises several questions.

One example is: how will Basel II impact banks domiciled and/or operating in the emerging markets? Much like the 1996 Market Risk Amendment to Basel I (BCBS (1996)), Basel II was designed largely with large, internationally active banks in mind. For market

risk this has created some perverse incentives, namely that the standardized approach often yields much lower regulatory capital levels than the internal models approach, precisely the opposite of what was intended. For example, the charge for interest rate risk reflects, for instruments of 1-2Y maturity, a yield change of only 90 basis points. While this may indeed be a large movement in the G-7 fixed income markets, it occurs with much greater regularity in many emerging markets. If the risk-sensitive parameter values of the standardized approach for credit risk in the New Basel Accord are similarly “too low,” the Accord will lack the desired incentive to have banks migrate toward the IRB approach. It remains an open question just how different the impact between the standardized and IRB approaches are in the emerging market context, and whether that difference provides the right incentives.

A second example is the Accord’s impact, if any, on the business cycle, the so-called pro-cyclicality debate. The basic concern is that tying banks' capital to dynamically changing credit ratings will result in pro-cyclical behavior on the part of the banks. When the business environment softens, firms (borrowers) become riskier as predicted by the credit risk (internal ratings) models, which often have obligor profitability as a driver. As a result, banks need to hold more capital against loans to those firms. Yet firms may need additional funds precisely during those challenging times to ensure that they are in a viable position when demand resumes.

Of course, bank lending is already pro-cyclical (Lown, Morgan and Rohatgi (2000)), and it is not clear that the new Accord will necessarily exacerbate this pro-cyclicality. Business cycle fluctuations can have a major impact on credit portfolio loss distributions. Carey (2002), using re-sampling techniques, shows that mean losses during a recession such as 1990/91 in the U.S. are about the same as losses in the 0.5% tail during an expansion.

Bangia et al. (2002), using a regime switching approach, find that capital held by banks over a one-year horizon needs to be 25-30% higher in a recession than in an expansion.

To be sure, it is not clear how to detect pro-cyclicality, even if it were to exist. Are losses higher in a recession because of a bad draw from the loss distribution or because cyclical factors affecting the loss distribution have shifted? Allen and Saunders (2002) make the important distinction between ex post loss realization (the loss distribution is fixed) vs. ex ante changes in credit exposure (the entire loss distribution shifts in response to macroeconomic factors). Allen and Saunders (2002) and Borio, Furfine and Lowe (2001) claim that the New Basel Accord would exacerbate pro-cyclicality, while Carpenter, Whitesell and Zakrajsek (2001) argue otherwise.

All of these studies are conducted under a similar ceteris paribus assumption as the calibration effort under the Quantitative Impact Studies.¹⁵ Yet, analogous to a Lucas-style critique, the very introduction of the New Basel Accord will likely influence bank behavior. For all banks, the increased transparency achieved by disclosing many of those risk metrics to the market through Pillar 3 may affect their behavior. For some banks, the output of the risk calculations under the New Basel Accord may serve as useful inputs to many decision points for bank management, including capital allocation between different lending activities, risk-based pricing and performance measurement. The potential and channels for changing bank behavior is an important issue that merits more research.

¹⁵ Basel Committee for Banking Supervision (2002).

5.2. Risk Analytics

This may be the largest grouping of attendant research questions. We will distinguish between validation of models, the four IRB parameters of *PD*, *LGD*, *EAD* and *M*, correlations and portfolio aggregation, operational risk metrics and finally, coherent risk measures. We will briefly give some highlights in each area.

5.2.1. Risk Analytics: Validation

In Section 4.1 we laid out some of the key elements of the credit risk portion of the New Basel Accord, in particular the IRB (internal ratings based) approach to estimating credit risk. Of the four parameters or variables, the probability of default (*PD*), loss given default (*LGD*), exposure at default (*EAD*) and maturity (*M*), *PD* arguably serves as the cornerstone. At a practical level, banks implement *PD* estimates through a rating tool, where each obligor is assigned a credit rating, effectively a summary measure of the obligor's creditworthiness. The key question here may simply be: how do we recognize a good or bad rating system? Backtesting à la VaR models for market risk is going to be very hard for the simple reason that defaults, the event forecast by rating tools, happen rarely (Lopez and Saidenberg (2000)). Judging the performance of a model from a single year's results is difficult because of the limited number of defaults and because common macroeconomic conditions affect all borrowers. Dependence on common factors makes it difficult to assume within year independence. This will affect test statistics, which typically make *iid* assumptions.

More broadly, there are two key related, yet distinct, elements in the evaluation (or validation) of banks' internal ratings systems by banks or supervisors. The first element is the accuracy of the ratings systems or models, which refers to whether the ratings reflect the actual credit quality of the bank's borrowers on an ex ante basis. However, since the credit

quality of borrowers is never truly known, absolute evaluations of accuracy may not be possible. Evaluations of accuracy relative to other ratings system, such as by independent ratings agencies, other firms' internal ratings, or model-generated ratings, are possible and should be evaluated.

The second element of internal rating systems or models evaluations is their consistency. The intuition here is that if a ratings system is well defined, then ratings across time and across borrowers should be predictable. That is, based on new information at a different point in time or for a new borrower, the system should generate a rating that is reasonable related to those already assigned.

5.2.2. Risk Analytics: *PD*

The probability of default is arguably the most important parameter in the IRB approach. Some of the difficulties of estimation and model validation have been discussed above in Section 5.2.1. The *PD* is a real number defined on the unit interval. Credit ratings, such as those assigned by rating agencies, are discrete.¹⁶ What is the appropriate mapping from one to the other? How many buckets or ratings should a rating system have? How does one know if there are too few or too many? Even if the bank can answer these questions for themselves, how should supervisors examine and monitor these rating systems?

Another relevant aspect of *PD* and rating is the process of ratings migration. Credit migration or transition matrices characterize the past changes in credit quality of obligors (typically firms) and are a convenient summary of credit behavior in a portfolio; the default probability is simply the last column of this matrix. There are different methods for estimating this matrix from ratings histories from either public bonds or internal customers,

some less efficient than others. Schuermann and Jafry (2003) explore whether and by how much it matters which of these methods are used (it can matter a lot) for annual migration matrices. In addition, these matrices are known to exhibit non-Markov behavior (Lando and Skodeberg (2002)) and sensitivity to the business cycle (Nickell, Perraudin and Varotto (2000) and Bangia et al. (2002)).

5.2.3. Risk Analytics: *LGD*, *EAD* and *M*

There are several ways of measuring *LGD*:

1. Market *LGD*: observed from market prices of defaulted bonds or marketable loans soon after the actual default event
2. Workout *LGD*: The set of estimated cash flows resulting from the workout and/or collections process, properly discounted, and the estimated exposure
3. Implied Market *LGD*: *LGDs* derived from risky (but *not* defaulted) bond prices using a theoretical asset-pricing model.

Banks typically have the second type at their disposal, though it is helpful to compare them, whenever possible, against the other two types. A critical assumption in all three methods is the appropriate discount rate. It is by no means obvious which discount rate to apply. In principle the correct rate would be for an asset of similar risk. Importantly, once the obligor has defaulted, the bank is an investor in a defaulted asset and should value it accordingly. Inappropriate candidates include the coupon rate (set ex ante of default, so too low) and the bank's hurdle rate (unless the bank only invests in very risky assets like defaulted debt instruments, probably too low). Estimating reliable risk-adjusted return measures on recoveries remains an important task.

¹⁶ For a review of the use of rating systems at U.S. banks, at least through the late 1990s, see Treacy and Carey

We do know a little about what drives the variability in *LGD*. It seems to matter where the debt instrument is in the capital structure of the defaulted firm and whether the debt is secured (Altman and Kishore (1996), Gupton, Gates and Carty (2000)). *LGDs* exhibit strong business cycle sensitivities (Frye (2000), Altman, Brady, Resti and Sironi (2002), Hu and Perraudin (2002)), and there is some systematic variation by industry (Altman and Kishore (1996)), although the recent default experience in the telecommunications and broadcasting sectors may have changed some of those results in non-trivial ways. Little is known about recovery variability in the emerging markets.

There are fewer empirical studies on *EAD*. For a term loan, *EAD* is rarely ambiguous. This is not the case for facilities such as lines of credit where a borrower is theoretically able to draw down at will up to the committed line of the facility. Moreover, as financial distress worsens, a borrower will typically draw down as much as possible on existing unutilized facilities in order to avoid default. In the foundation sub-approach of IRB, *EAD* is also based on supervisory values in cases where the measurement is not clear. For instance, *EAD* is 75% for irrevocable undrawn commitments. However, under the advanced sub-approach, *EAD* may be determined by the bank via a model.

For facilities where exposure and hence *LGD* are uncertain, the loan equivalency factor (*LEQ*) represents a quantitative estimate of how much of the commitment will be drawn down by a defaulting borrower. *LEQs* should be differentiated across both credit quality and facility type. Empirical work on this topic is sparse. As part a broader study of loan performance, Asarnow and Marker (1995) analyze the performance of large corporate commitments at Citibank from 1988 – 1993 and show the importance of credit (debt) rating,

(2000).

particularly at the speculative end. More recently, Araten and Jacobs (2001) evaluate the behavior of over 400 facilities from defaulted borrowers over a six-year period and find a highly significant increase in *LEQs* relative to time-to-default across all rating grades and a somewhat weaker relationship between *LEQs* and ratings grades. They note that similar to *LGDs*, observed or realized *LEQs* are widely dispersed.

5.2.4. Risk Analytics: Correlations and Portfolio Aggregation

The model building component around the IRB approach is largely focused on exposure-level risk modeling: what is the *PD* and *LGD* of a particular obligor or facility? To compute risk (and capital) at portfolio level, one needs to make some assumption about the joint default (loss) process or distribution. Broadly there are two approaches to computing joint losses: direct estimation with data or indirectly through a structural model of firm valuation and default. The binding constraint typically is data availability: defaults are rare, joint defaults even more so.

The direct approach would take a large data set with a long history and proceed to computing default and loss correlations directly within a time window large enough, say monthly or quarterly, to capture sufficient simultaneous default events. To do this properly, one really needs large amounts of data, restricting the application of this approach to consumer banking portfolios such as credit card.

The indirect approach uses a structural model of default, e.g. the Merton model. Since default data is very sparse, the idea is to focus modeling effort instead on the default process in a space where the data is denser. The Merton model, for example, looks at evolution of a firm's balance sheet to arrive at a distance-to-default measure. This broad modeling approach is elegant in the sense that any structural approach is, but also tricky. There may be a large

class of observationally equivalent structural models which explain the default process; how does one choose between them? The Merton model is indeed widely used, and there is some evidence that it does well.¹⁷ Moreover, the final capital value determined by the New Basel Accord implicitly assumes a single-factor Merton-type model, where the asset correlation is a weighted average of 12% and 24% (see equation (1)).¹⁸

Recently there has been exciting progress in the area of modeling joint default and loss. One method in particular holds great promise: the computation of the joint distribution using copulas. A copula is a function that links the marginals to the joint distribution. Beyond allowing for the aggregation of diverse marginal distributions which capture some of the essential features found in risk management, like fat tails, copulas also allow for richer dependence structure than allowed for by simple models like the multivariate normal. For a review of the theory, see Nelsen (1998). Embrechts, McNeil and Straumann (1999, 2002) were among the first to introduce this toolkit to the finance literature. Li (2000) provides an application to credit risk and credit derivatives.¹⁹ These methods are now being put to the test, and we eagerly anticipate their reported performance.

5.2.5. Risk Analytics: Op Risk Metrics

Arguably, the timing and degree to which an internal models approach to computing capital has become part of the regulatory process is inversely related to the level of difficulty in modeling the risk types and how much data is available. An internal models approach for market risk became embedded in the regulations with the 1996 amendment to the first Basel

¹⁷ For a discussion of the power of Merton default prediction models see Falkenstein and Boral (2001) and Gemmill (2002) who find that the Merton model generally does well in predicting default (Falkenstein and Boral) and credit spreads (Gemmill).

¹⁸ See also Gordy (2002)

Accord (BCBS (1996)). In the New Basel Accord, the IRB approach allows for some, though not complete, internal modeling of credit risk capital. Operational risk capital is new territory for capital regulation, and this is driven to some extent by the difficulty in modeling this risk type.²⁰

Large, institution-threatening operational risk events are by definition rare. Smaller ones may or may not be relevant for learning about the operational risk event data generating mechanism. And therein lies one of the fundamental issues in modeling operational risk: the events are both rare and hard to identify. Moreover, one can think of many examples where it is not obvious whether an event should be classified as an operational risk event or part of market or credit risk. For instance, if in the process of marking-to-market the options book the institution used a “wrong” or “mis-specified” model: is that market or op risk? Another example would be the classification of credit card losses due to fraud as either credit or operational risk.

When it comes to formal modeling, several (Embrechts, Klüppelberg and Mikosch (1997), papers collected in Embrechts (2000)) have argued that the toolkit of insurance risk may be a useful place to look. One example is extreme value theory (EVT) which seeks to model extreme events outside the range of historical experience. In its basic formulation, the probabilistic theory assumes that the underlying event process is *iid*, and by focusing on the tail of the observed distribution we can make inference about the very far, not-yet-seen tail.

However, there is a sharp developmental contrast between the probabilistic and statistical aspects of EVT. The probability theory is elegant and voluminous, whereas the

¹⁹ Wang (1999, 2002) proposes an application to insurance with particular emphasis to enterprise-wide risk management (Wang, 2002).

²⁰ See also Netter and Poulsen (2003) for an overview.

statistical theory remains largely skeletal. This is particularly unfortunate because empirical applications must rely on statistical inference.²¹ For instance, if this insurance approach is indeed promising, then those risks could be insured much like other events are insured by property and casualty insurers. A proper understanding of the event generating process is needed to appropriately price those contracts.

5.2.6. Risk Analytics: Relevant Risk Summaries

If the broad regulatory goal is to make capital regulation more sensitive to the underlying risk, what measure of risk is the right one to target? Many of the risk measurement tools are variants of VaR (value-at-risk). VaR is defined as the loss to the portfolio due to an adverse market move that is only exceeded $\alpha\%$ of the time (e.g. $\alpha = 2.5\%$, 1%). It is thus a scalar measure (a summary) of a very high dimensional problem.

Christoffersen and Diebold (2000) and Berkowitz (2001) argue that rather than focusing on just one number such as VaR, risk managers and, implicitly, regulators should focus on the whole density function of returns, perhaps using techniques such as those laid out in Diebold, Gunther and Tay (1998) and Berkowitz (2001). Nonetheless, interest in a simpler summary measure continues. What standards should such a summary measure meet and how do the regulatory approaches currently in use measure up to these standards?

Artzner, Delbaen, Eber, and Heath (1997, 1999) lay out a set of criteria necessary for what they call a “coherent” measure of risk. They include homogeneity (larger positions bring greater risk), monotonicity (greater returns come with greater risk), sub-additivity (the risk of the sum cannot be greater than the sum of the risks) and the risk-free condition (if the entire portfolio is invested in the risk-free asset, it should be riskless). Importantly, VaR does

²¹ See also Diebold, Schuermann and Stroughair (1998) for a more extensive assessment of the use of EVT in

not satisfy the sub-additivity condition, implying that a firm could concentrate all of its tail risks in one exposure in such a way that the risk borne by that exposure appears just beyond the overall portfolio VaR threshold.

One potential solution to this shortcoming is to include the expected shortfall or exceedence. It answers the simple question: how bad is bad? Borrowing from the insurance literature, authors such as Embrechts, Klüppelberg and Mikosch (1997), Artzner, Delbaen, Eber, and Heath (1997, 1999), Nefci (2000) and Basak and Shapiro (2001), among others, suggest looking at the beyond-VaR region.

The expected shortfall measure describes the expected loss given that $\text{VaR}(\alpha)$ has been exceeded. Taking the mean is a very simple summary statistic of the beyond-VaR tail. However, the risk manager (and regulator) might care differently about the probability mass being piled up near the VaR threshold or further away (i.e. deeper into the tail), prompting one to consider estimating higher moments of the tail region (standard deviation, skewness, and so on). It becomes clear again that the information loss from attempting to summarize the portfolio risk in a single number from the whole density could be substantial.

5.3. Pillars 2 and 3: Supervisory Review, Disclosure and Market Discipline

Estrella (2000) provides a thoughtful discussion of the difficulties and trade-offs encountered in design of regulation for financial institutions. They include the different goals and objective functions of the different constituencies; the desire for both simplicity (emphasis on rules) and flexibility (emphasis on supervision); at the same time we want to

allow for market forces to provide a powerful monitoring and correction mechanism.²² The framework of the New Basel Accord is partly motivated by wanting to strike a balance among these apparently competing forces.

The second pillar can be thought of as the main load-bearing column of the regulatory framework. In the words of Estrella (1998, p. 192), this pillar would allow regulators to reap “the benefits of informed supervision. Mechanical formulas may play a role in regulation, but they are in general incapable of providing a solution to the question of how much capital a bank should have.” Especially for a large, complex financial institution, the supervisory review is likely to be far more important than the rules-based approach. It would enable the supervisor to evaluate the adequacy of an institution’s internal risk management and capital decision processes along a number of dimensions. Importantly, this pillar should be a flexible approach that allows for differences across institutions. Such differentiation is necessary to accommodate variations in business mix, risk profile, legal structure, and level of sophistication.

The third pillar would leverage market judgements on capital adequacy. In the end, the market’s judgement of capital for the holding company (and potentially individual subsidiaries) will be decisive, through its influence on pricing and access to funding. While it is attractive from a theoretical standpoint to place great weight on the market’s consensus, in practical terms there are too many limitations in current accounting conventions and disclosure standards for this pillar to be sufficient on its own.

²² Estrella (2000) and Santos (2001) stress that risk and capital are hard to determine in the presence of safety net such as deposit insurance, and that the two design problems (capital adequacy, deposit insurance) should be addressed simultaneously (Santos (2001)).

The basic idea behind Pillar 3 is for the banks to tell market participants the relevant and important risk measures. Financial institutions are particularly opaque, however, making assessments by rating agencies and equity analysts more difficult. Morgan (2002) measures this opacity by showing that bond raters disagree more about banks and insurance companies than about any other kind of firm. Moreover, in Section 5.2.6, we showed how hard it is to agree on the relevant summary statistic for a bank's risk profile.

To some degree, the disclosure experiment has already been running for market risk. Several papers have examined the accuracy and information content of VaR model estimates with subsequent bank performance. Berkowitz and O'Brien (2002) compare daily VaR forecasts with next day trading results using a sample of large U.S. banks containing confidential supervisory data, i.e. data which is *not* available to market participants. While the VaR models provide a conservative estimate of the 99% tail on average, there is substantial variation across institutions. Moreover, they demonstrate that a simple GARCH model based on daily trading P&L outperforms the VaR models. Jorion (2002) and Hirtle (2003) examine the information content of VaR reporting. Both studies suggest that such disclosures are indeed informative. Jorion (2002) reports that VaR disclosures predict variability in trading revenues. Similarly Hirtle (2003) finds that reported market risk capital is useful for predicting changes in market risk exposure over time for individual banks; however, such disclosures provide little information about differences in market risk exposure across banks. Finally Estrella, Park and Peristiani (2000) examine the problem of predicting bank failure and find that the basic leverage ratio is no worse than the Basel I risk-based capital measure. The more risk sensitive measures in Basel II should prove to be more informative.

6. Final Comments

Given its objectives and strong analytical foundations the New Basel Accord opens the door to many research questions. This paper has broken down some of these questions into three groups: the impact of the proposal on the global banking system through possible changes in bank behavior; a set of issues around risk analytics such as model validation, correlations and portfolio aggregation, operational risk metrics and relevant summary statistics of a bank's risk profile; issues brought about by Pillar 2 (supervisory review) and Pillar 3 (public disclosure). The output of the risk calculations under the New Basel Accord may also change bank behavior as some of the internal risk metrics are disclosed to the public. With this in mind, our view for a research agenda going forward is one focused less on regulatory design. Instead the agenda might be better oriented towards understanding the Accord's likely impact on the banking system, possible changes in bank behavior through different uses of the risk measurement framework, and important analytical issues around model development and validation in both credit and operational risk narrowly and the development of relevant risk summary statistics more broadly. Without a doubt, given its scope and complexity, the Accord continues to provide many opportunities for researchers to contribute to the policy debate and implementation of these proposals.

References

- Allen, L. and A. Saunders (2002), "A Survey of Cyclical Effects in Credit Risk Measurement Models", mimeo, Stern School of Business, NYU; available at http://pages.stern.nyu.edu/~asaunder/procyclicality_allensaunders.pdf.
- Altman, E.I. and V.M Kishore, 1996, "Almost Everything You Wanted to Know about Recoveries on Defaulted Bonds", *Financial Analysts Journal*, November/December, 57-64.
- Altman, E., B. Brady, A. Resti and A. Sironi, 2002, "The Link between Default and Recovery Rates: Implications for Credit Risk Models and Procyclicality", NYU Stern School Salomon Center Working Paper.
- Araten, Michel and Michael Jacobs Jr., 2001, "Loan Equivalents for Revolving Credits and Advised Lines." *RMA Journal*, May 34-39.
- Artzner, P., Delbaen, F., Eber, J.M., Heath, D., 1999, "Coherent Measures of Risk," *Mathematical Finance* 9, 203-228.
- Artzner, P., Delbaen, F., Eber, J.M., Heath, D., 1997, "Thinking coherently," *Risk* 10 (11), 68-71.
- Asarnow, Elliot and James Marker (1995), "Historical Performance of the U.S. Corporate Loan Market: 1988 – 1993", *Commercial Lending Review*, Spring, 13-32.
- Ball, Clifford A. and Hans R. Stoll, 1998, "Regulatory Capital of Financial Institutions: A Comparative Analysis," *Financial Markets, Institutions & Instruments* 7 (3), 1-57.
- Bangia, A., F.X. Diebold, A. Kronimus and C. Schagen and T. Schuermann, 2002, "Ratings Migration and the Business Cycle, With Applications to Credit Portfolio Stress Testing", *Journal of Banking & Finance*, 2002, (26: 2/3), 445-474.
- Basel Committee on Banking Supervision, 1988, "Internal Convergence of Capital Measurement and Capital Standards, <<http://www.bis.org/publ/bcbs04A.pdf>>, July.
- Basel Committee on Banking Supervision, 1996, "Amendment to the Capital Accord to Incorporate Market Risks (No. 24)", January.
- Basel Committee on Banking Supervision, 2001a, *The New Basel Capital Accord*, <<http://www.bis.org/publ/bcbsca.htm>>, January.
- Basel Committee on Banking Supervision, 2001b, *The Internal Ratings Based Approach*, <<http://www.bis.org/publ/bcbsca.htm>>, May.
- Basel Committee on Banking Supervision, 2002, *Quantitative Impact Study 3 Technical Guidance*, <<http://www.bis.org/publ/bcbsca.htm>>, January.
- Basel Committee on Banking Supervision, 2003, *Third Consultative Paper*, <http://www.bis.org/bcbs/bcbsep3.htm>, April.
- Basak, S. and A. Shapiro, 2001, "Value-at-Risk Based Risk Management: Optimal Policies and Asset Prices," 2001, *Review of Financial Studies*, 14(2), 371-405.
- Benston, George J. and George Kaufman, 1995, "Is the banking and payment system fragile?" *Journal of Financial Services Research*, 9.

- Berger, A.N., R.J. Herring and G.P. Szegő, 1995, "The Role of Capital in Financial Institutions", *Journal of Banking & Finance*, 19, 393-430.
- Berkowitz, Jeremy, 2001, "Testing the Accuracy of Density Forecasts, applications to Risk Management," *Journal of Business and Economic Statistics*, 19, 465-474.
- Berkowitz, Jeremy and Paul O'Brien, 2002, "How accurate are Value-at-Risk Models at Commercial Banks?," *Journal of Finance* 57 (3).
- Board of Governors of the Federal Reserve System, 2002, *Capital Adequacy Guidelines*, 12 CFR 225, appendix A.
- Borio, C, C Furfine and P Lowe, 2001, "Procyclicality of the Financial System and Financial Stability: Issues and Policy Options", *BIS Working Papers*, no 1.
- Calem, P. and R. Rob, 1999, "The Impact of Capital-Based Regulation on Bank Risk-Taking", *Journal of Financial Intermediation* 8, 317-352.
- Caprio, G. and D. Klingebiel, 1996, "Bank Insolvencies: Cross-Country Experience", World Bank, Policy Research Paper #1620, July.
- Carey, M. (2002), "A Guide to Choosing Absolute Bank Capital Requirements", *Journal of Banking & Finance* 26 (5), 929-951.
- Carpenter, S.B., W. Whitesell and E. Zakrajšek (2001), "Capital Requirements, Business Loans and Business Cycles: An Empirical Analysis of the Standardized Approach in the New Basel Accord", Federal Reserve Board, Finance and Economics Discussion Series # 2001-48.
- Christoffersen, P. and F.X. Diebold, 2000, "How Relevant is Volatility Forecasting for Financial Risk Management?" *Review of Economics and Statistics* 82, 12-22.
- Crouhy, M., D. Galai and R. Mark, 2001, *Risk Management*, New York: McGraw Hill.
- Dewatripont, M. and J. Tirole, 1994, *The Prudential Regulation of Banks*, Cambridge, MA: MIT Press.
- Diamond, D.W. and P.H. Dybvig, 1983, "Bank Runs, Deposit Insurance and Liquidity", *Journal of Political Economy* 91, 401-419.
- Diebold, F.X., T.A. Gunther and A.S. Tay, 1998, "Evaluating Density Forecasts", *International Economic Review* 39, 863-883.
- Diebold, F.X., T. Schuermann and J. Strouhair, 1998, "Pitfalls and Opportunities in the Use of Extreme Value Theory in Risk Management," Ch. 1 in A.-P. N. Refenes, A.N. Burgess and J.D. Moody (eds.), *Advances in Computational Finance*. Amsterdam: Kluwer Academic Publishers.
- Embrechts, P., C. Klüppelberg and T. Mikosch, 1997, *Modelling Extremal Events for Insurance and Finance*, New York: Springer Verlag.
- Embrechts, P., A. McNeil and D. Straumann, 1999, "Correlation and Dependence in Risk Management: Properties and Pitfalls," Working Paper, ETH Zürich. Forthcoming in M. Dempster (Ed.), 2001, *Risk Management: Value at Risk and Beyond*, Cambridge, UK: Cambridge University Press.

- Embrechts, P. (editor), 2000, *Extremes and Integrated Risk Management*, London, UK: Risk Publications.
- Estrella, A., 1998, "Formulas or Supervision? Remarks on the Future of Regulatory Capital", *Federal Reserve Bank of New York Economic Policy Review*, October, 191-200.
- Estrella, A., 2000, "Regulatory Capital and the Supervision of Financial Institutions: Some Basic Distinctions and Policy Choices", in A. Santomero, S. Viotti and A. Vredin (eds.) *Challenges for Modern Central Banking*, Stockholm: Swedish Riksbank (forthcoming).
- Estrella, A., S. Park and S. Peristiani, 2000, "Capital Ratios as Predictors of Bank Failures" *Federal Reserve Bank of New York Economic Policy Review* 6 (2) 33-52.
- Falkenstein, E. and A. Boral (2001), "Some empirical results on the Merton Model", *Risk Professional*, April 2001.
- Frye, J., 2000, "Depressing Recoveries", Chicago Fed working paper, an abridged version appeared in *Risk*, November.
- Gemmill, G. (2002), "Testing Merton's Model for Credit Spreads on Zero-Coupon Bonds", Faculty of Finance, City University Business School; available at http://www.staff.city.ac.uk/g.gemmill/working_papers/credit_spread.pdf.
- Gordy, M.B., 2002, "A Risk Factor Model Foundation for Ratings Based Capital Rules" *Board of Governors of the Federal Reserve System Finance and Economic Discussion Series* 2002-55.
- Gupton, G., D. Gates, and L. Carty, 2000, "Bank Loan Loss Given Default." *Moody's Special Comment*, November.
- Hirtle, B., 2003, "What Market Risk Capital Reporting Tells Us About Bank Risk", *Federal Reserve Bank of New York Economic Policy Review* (forthcoming).
- Hu, Y-T and W. Perraudin, 2002, "The Dependence of Recovery Rates and Defaults", CEPR working paper.
- Joint Forum, 2001, *Risk Management Practices and Regulatory Capital, Cross-Sectoral Comparison*, November; available at <http://www.bis.org/publ/joint03.pdf>.
- Jorion, P., 2002, "How Informative are Value-at-Risk Disclosures?", *Accounting Review* 77 (October), 911-931.
- Lando, D. and T. Skødeberg, (2002), "Analyzing Ratings Transitions and Rating Drift with Continuous Observations", *Journal of Banking & Finance* 26 (2-3), 423-444.
- Li, David X., 2000, "Default Correlation: A Copula Approach", *Journal of Fixed Income*, March, 43-54.
- Lopez, J.A. and M. Saidenberg, 2000, "Evaluating Credit Risk Models", *Journal of Banking & Finance* 24 (1/2), 151-167.
- Lown, C.S., D.P. Morgan, and S. Rohatgi, 2000, "Listening to Loan Officers: Commercial Credit Standards, Lending and Output", *Federal Reserve Bank of New York Economic Policy Review* 6 (2), 1-16.

- Merton, R., 1974, "On the pricing of corporate debt: the risk structure of interest rates", *Journal of Finance* 29, 449-470.
- Mishkin, F.S., 1997, "Evaluating FDICIA", *Research in Financial Services: Private and Public Policy* 9, 17-33.
- Morgan, D.P., 2002, "Rating Banks: Risk and Uncertainty in an Opaque Industry", *American Economic Review* 92 (4), 874-888.
- Neftci, S.N., 2000, "Value at Risk Calculations, Extreme Events and Tail Estimation", *Journal of Derivatives* 8, 23-37.
- Nelsen, Roger B., 1998, *An Introduction to Copulas*, Lecture Notes in Statistics, 139, New York: Springer Verlag.
- Netter, Jeffrey M. and Annette B. Poulson, 2003, "Operational Risk in Financial Service Providers and the Proposed Basel Capital Accord: An Overview", Terry College of Business, University of Georgia, Department of Banking and Finance Working Paper. available at <http://papers.ssrn.com/paper.taf?abstract_id=369581>.
- Nickell, P, W. Perraudin and S. Varotto, 2000, "Stability of Rating Transitions", *Journal of Banking & Finance*, 24, 203-227.
- Santos, J.A.C., 2001, "Bank Capital Regulation in Contemporary Banking Theory: A Review of the Literature", *Financial Markets, Institutions & Instruments* 10 (2), 41-84.
- Saunders, Anthony and Linda Allen, 2002, *Credit Risk Measurement- New Approaches to Value at Risk and Other Paradigms*, 2nd Ed., New York: John Wiley & Sons.
- Schuermann, T. and Y. Jafry (2002), "Estimating Credit Migration Matrices: Measurement Matters", mimeo, Federal Reserve Bank of New York
- Treacy, W.F. and M. Carey, 2000, "Credit Risk Rating Systems at Large U.S. Banks", *Journal of Banking & Finance*, 24, 167-201.
- Wang, Shaun S., 1999, "Aggregation of Correlated Risk Portfolios: Models & Algorithms", Casual Actuarial Society Theory of Risk Working Paper; available at <http://casact.org/cofor/Wang.pdf>.
- Wang, Shaun S., 2002, "A Set of New Methods and Tools for Enterprise Risk Capital Management and Portfolio Optimization", CAS Forum Summer 2002; available at <http://www.casact.org/pubs/forum/02sforum/02sf043.pdf>.